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THESIS

WARGAMING AND SIMULATION AS TOOLS FOR CONOPS DEVELOPMENT

by

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September 2004

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WARGAMING AND SIMULATION AS TOOLS FOR CONOPS DEVELOPMENT

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ABSTRACT

The purpose of this thesis is to use wargaming and simulation to gain insight into the effective employment of a new Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) system, the Adaptive Joint C4ISR Node (AJCN). The AJCN provides the supported commander with several capabilities, to include: range extension, waveform bridging, signal intelligence, electronic warfare, and information operations. Two methods are used to gain insight to the support generation of the concept of operations for the AJCN's employment. The first method is wargaming. The wargaming method utilized a class of NPS students and the JCATS combat simulation model. The wargaming generated insights concerning the AJCN's employment. The second method is the use of a constructive simulation model, POA 2. Insights gained from the two methods include: the need for commanders to differentiate the AJCN and its supporting platform; the need for effective information processing techniques; the importance of maintaining at least two-tiers of AJCN coverage to enhance situational awareness of the supported units.

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TABLE OF CONTENTS

I.	INTRODUCTION.....	1
A.	PURPOSE.....	1
B.	BACKGROUND	1
C.	RESEARCH QUESTIONS	3
D.	METHODOLOGY	4
E.	THESIS OBJECTIVES.....	8
F.	THESIS SCOPE.....	8
II.	ADAPTIVE JOINT C4ISR NODE (AJCN).....	9
A.	ADAPTIVE JOINT C4ISR NODE (AJCN).....	9
1.	Communications.....	9
a.	<i>Range Extension</i>	9
b.	<i>Waveform Bridging</i>	10
c.	<i>Reach Back</i>	11
2.	Signal Intelligence (SIGINT)	12
3.	Electronic Warfare (EW)	12
4.	Information Operations (IO)	12
B.	AJCN PLATFORMS	13
1.	RQ-5/Hunter.....	14
2.	KC-135 Stratotanker	15
3.	Global Hawk	15
III.	SCENARIO	17
A.	BACKGROUND	17
B.	WARGAME SCENARIO	18
C.	ANALYSIS SCENARIO	20
IV.	WARGAME.....	23
A.	WHAT IS A WARGAME?	23
B.	USE OF WARGAMING AS A CONOPS DEVELOPMENT TOOL.....	23
C.	WARGAME EXECUTION	25
V.	SIMULATION.....	27
A.	WHAT IS A CONSTRUCTIVE SIMULATION?	27
B.	USE OF SIMULATION AS A CONOPS DEVELOPMENT TOOL.....	28
C.	JCATS MODEL.....	32
D.	MODELING THE AJCN IN JCATS	36
1.	Human in the Loop (Wargame).....	37
a.	<i>Waveform Bridging</i>	37
b.	<i>SIGINT</i>	37
c.	<i>Jamming</i>	38
2.	JCATS - Closed Loop Runs	38
a.	<i>Waveform Bridging and SIGINT</i>	38
b.	<i>Electronic Warfare (EW)</i>	40

3.	One-Tier versus Three-Tier	42
4.	Experimental JCATS Executions	42
5.	Database Confound	42
E.	POA 2 MODEL	52
F.	MODELING THE AJCN IN POA2	59
VI.	ANALYSIS	65
VII.	CONCLUSION	79
A.	PURPOSE OF THE STUDY	79
B.	WARGAME INSIGHTS	79
1.	High Priority Target	79
2.	Vulnerable During Early Entry Operations	80
3.	AJCN Seen as Its Platform	81
4.	Need for Effective Information Processing	82
5.	C2 of AJCN	83
6.	Adjustable "Radius of Coverage" for AJCN Waveform Bridging	83
C.	SIMULATION INSIGHTS	84
1.	Careful Assessment of Supporting Platform Performance Parameters	84
2.	Use of "Decoy" Systems During Initial Phase of Battle	85
3.	Maintain 2-Tier Coverage	85
D.	FUTURE WORK	85
1.	Continued AJCN Analysis	86
2.	Database Analysis of DoD Constructive Simulations	86
	LIST OF REFERENCES	87
	INITIAL DISTRIBUTION LIST	91

LIST OF FIGURES

Figure 1.	Pictorial representation of AJCN performing Waveform Bridging and SIGINT Missions.....	11
Figure 2.	AJCN Mission Summary.....	13
Figure 3.	Hunter UAV	14
Figure 4.	KC-135 Stratotanker.....	15
Figure 5.	Global Hawk UAV.....	16
Figure 6.	Proposed CONOPS Development Methodology	31
Figure 7.	"All Kills" Summary Report: Detailed report of shooter-target pairs sorted by time and type of kill	33
Figure 8.	"System Kills Report": Summary report of total quantities of systems killed	34
Figure 9.	"Direct Fire Ranges (Missed)": Graphical summary of shots that were fired and missed their designated targets	34
Figure 10.	"Forces Remaining": Graphical representation of "friendly" and "enemy" forces levels based on the percent remaining over time	35
Figure 11.	JCATS VISTA Editor	35
Figure 12.	PhPk Curve Assignment Editor: Links the munition and its target with a Ph and Pk curve.....	36
Figure 13.	Initial Array of Forces for "Closed-Loop" Scenario.....	40
Figure 14.	AJCN sending off a "jamming signal" to a targeted enemy system	41
Figure 15.	Munition Editor-General: User designates the munition type, fire modes, mission, and munition reliability	43
Figure 16.	Munition Editor-Conventional: User designates guidance type, ranges, and munition velocity	44
Figure 17.	PhPk Curve Assignment Editor and Ph and Pk Table Examples	45
Figure 18.	PhPk Curve Assignment Editor: Munitions not "paired" with a target will not engage that particular target, regardless of what might occur in the "real world"	46
Figure 19.	Weapon Editor: Requires the user to define several operational parameters of the weapon.....	47
Figure 20.	Sensor Editor: List of sensors generated in the database	47
Figure 21.	Sensor Editor-Data input window requiring user to define several parameters describing the functionality of the sensor.....	48
Figure 22.	System Editor: User defines the platform's characteristics, platform's weapons with their associated munitions and sensors.....	48
Figure 23.	JCATS Ph Curve Data for 40mm Munition	51
Figure 24.	POA2 Ammunition Properties for 40mm Munition	51
Figure 25.	Combat Phase Report.....	53
Figure 26.	Data View for Ammunition Properties for Armor Piercing 7.62mm ball.....	56
Figure 27.	Unit Information Details	57
Figure 28.	Game Results and MOE Report.....	59

Figure 29.	Communications and Jamming Systems Table.....	61
Figure 30.	POA2 Results Table (Mean Values for all Data Recorded)	65
Figure 31.	Mean Attrition Data for US and Chinese Forces	66
Figure 32.	Mean Attrition Data for US and Chinese Forces	67
Figure 33.	MOE #1 Mean Data	68
Figure 34.	MOE #1 Boxplots	69
Figure 35.	MOE #2: Fractional Exchange Ratio Mean Data	71
Figure 36.	MOE#2: Fractional Exchange Ratio Boxplots.....	71
Figure 37.	US Fratricide Mean Data	73
Figure 38.	MOE #3: US Friendly Fire Boxplots.....	73
Figure 39.	MOE #4: Acquisition Rate Mean Data	76
Figure 40.	MOE #4: Acquisition Rate Boxplots.....	76
Figure 41.	MOE #5: AJCN Survivability Mean Data	78
Figure 42.	MOE#5: AJCN Survivability Boxplots	78

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LIST OF SYMBOLS, ACRONYMS, AND/OR ABBREVIATIONS

ACTD	Advanced Concept Technology Demonstration
ADC2	Aide de Camp 2
AFSOR	Air Force Office of Scientific Research
AI	Artificial Intelligence
AJCN	Adaptive Joint C4ISR Node
AWS	Analyst Work Station
C2	Command and Control
C4I	Command, Control, Communications, Computers and Intelligence
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
CEM	Concepts Evaluation Model
CINC	Commander in Chief
CJTF	Combined Joint Task Force
CNA	Computer Network Attack
COA	Course of Action
CoCom	Combatant Commander
CONOPS	Concept of Operations
CRS	Control and Reporting Segment
DMSO	Defense Modeling and Simulation Office
DoD	Department of Defense
DS	Direct Support
EA/Can	Electronic/Computer Network Attack
EW	Electronic Warfare
FER	Fractional Exchange Ratio
FO	Forward Observer
GUI	Graphical User Interface
HE	High Explosive
HPT	High Priority Target
IO	Information Operations
IPB	Intelligence Preparation of the Battlefield
ISR	Intelligence, Surveillance, and Reconnaissance
IW	Information Warfare
JCATS	Joint Conflict and Tactical Simulation
JCIDS	Joint Capabilities and Integration Development System
JFCOM	Joint Forces Command
JTF	Joint Task Force
JTRS	Joint Tactical Radio System
JWICS	Joint Worldwide Intelligence Communications System
LOS	Line of Sight
MOE	Measure of Effectiveness
MPS	Mission Payload Segment
OPCON	Operational Concept

OPLAN	Operational Plan
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
PA&E	Program Analysis and Evaluation
PH	Probability of Hit
PK	Probability of Kill
PLA	Peoples Liberation Army
POA2	Point of Attack 2
PPBES	Planning, Programming, Budgeting, and Execution System
PRC	Peoples Republic of China
PSYOPS	Psychological Operations
SIGINT	Signal Intelligence
SINGARS	Single Channel Ground and Airborne Radio System
SIPRNET	Secure Internet-Protocol Router Network
STEP	Simulation, Test and Evaluation Process
T&E	Test and Evaluation
UA	Unit of Action
UAV	Unmanned Aerial Vehicle
UCAV	Unmanned Combat Air Vehicle
UE	Unit of Employment
USJFCOM	United States Joint Forces Command

I. INTRODUCTION

A. PURPOSE

The purpose of this thesis is to gain insights into the employment of an emerging Command, Control, Communications, Computers, and Intelligence (C4I) system as an enabler for network centric warfare. The system's intent is to provide interoperability between C4I systems in use throughout the Department of Defense (DoD) and the civilian sector. This thesis addresses insights on the employment of the system and helps contribute to the development of a CONOPS for the system.

B. BACKGROUND

"Network-centric warfare enables warfighters to leverage...information advantage to dramatically increase combat power through self-synchronization and other network-centric operations." [Ref. 1] It provides a means to achieve information superiority, a key component of Joint Vision 2010/2020 and the Department of Defense's Transformation Strategy.

The future force needs the ability to efficiently and reliably move the increasing amounts of digital data around the battlespace at the time and place of its choosing with a minimum of infrastructure. Continued modernization and digitization of the force increases the demand for information, sensors and bandwidth. Buying more existing platforms is not a viable answer. The heavy demand on command and control (C2) and intelligence, surveillance and reconnaissance (ISR) assets, indeed the electromagnetic spectrum itself, is unsupportable with our current, specialized systems. Communications at the theater/operational level, between the Joint Task Force and forward deployed elements, and between geographically separated elements, rely heavily on military and commercial satellite communications. Highly sophisticated sensors and Electronic Warfare (EW) systems are few in number, yet their demand is growing exponentially. In addition to the fiscal and logistical drain, continued use of these systems alone creates the possibility of single points of failure on the battlefield. Currently fielded capabilities consist primarily of single-mission systems that are tied to specific platforms. Even more importantly, these systems are not interoperable and are not able to support operations with disparate coalition and civil systems and thus inhibit our ability to achieve and sustain information superiority. [Ref. 2]

A key attribute of a network-centric force is the state of being effectively linked to distributed and disparate units and platforms on the battlefield. The historical process of service-independent acquisition prior to the Goldwater-Nichols Act of 1986 facilitated a significant hindrance to the new concept of network-centric warfare. [Ref. 8] Looking only within the communications realm, unit-level communication between units of different services is prohibitive solely on the basis of disparate technologies that cannot inherently translate each others' signals. As DoD transformation seeks to create Joint Task Forces that are composed of units from varied specialties and services, communication between these units is foundational to mission success. Until the core systems can be tailored to communicate with one another or replaced by a single DoD-service-wide system, bridges must be made to facilitate the Joint Task Forces' employment. Success in this endeavor must begin at the acquisition process.

The Planning, Programming, Budgeting, and Execution System (PPBES) is a cyclic process used by the Department of Defense to establish "the framework and process for decision making on future programs. The ultimate objective of PPBES is to provide the operational commanders-in-chief the best mix of forces, equipment, and support attainable within fiscal constraints." [Ref. 3] The goal of the PPBES supports the intent of the Goldwater-Nichols Act, which states that one of the functions of the Chairman of the Joint Chiefs of Staff is:

Advising the Secretary on the extent to which the program recommendations and budget proposals of the military departments and other components of the Department of Defense for a fiscal year conform with the priorities established in strategic plans and with the priorities established for the requirements of the unified and specified combatant commands. [Ref. 4]

Although the intent of the Goldwater-Nichols Act and PPBES is to promote jointness in the acquisition process, the individual services' are drawn to methods of self-preservation that promote their strengths on the battlefield. This practice results in independent and isolated development strategies that hinder and impede the ability of the various services to effectively operate together on the battlefield. The practice of filling the needs of the whole military by four or more

isolated services was found unacceptable by the current Secretary of Defense. [Ref. 5] The Secretary of Defense initiated studies into the methods used by the Department of Defense to develop, resource, and provide joint capabilities. The desired endstate; enforce the source of force requirement generation from the individual services to the Combatant Commanders (CoComs) [formerly CINCs]. The goal is to prevent the redundancy of capabilities among the services and force the cultural shift toward joint operations as the primary means of going to battle.

It is the independent services' system of acquisition that brought about the need for the system described in this thesis. Interoperability of C4I systems has been a continuing hindrance to the easy, efficient, and effective employment of joint forces acting in unison on the battlefield. [Ref. 6] The funding, research, and development of disparate C4I systems over the years has created a "wall" between the services. This "wall" is comprised of communication systems that can only interact with other systems inherent to the respective service. When the services are called upon to operate in conjunction with one another, "workarounds" and "quick-fixes" are employed to allow for the temporary, yet unreliable, interoperability of systems. Often the communication between services must go through the highest levels of command to a point where a "bridge" between C4I systems is present. [Ref.2, 5-6] The latter incurs great danger to the units operating within close proximity where timing of unit movement is critical.

Until the consequences of the former "stovepipe" methodology have been resolved from the foundational levels of military combat systems, the requirement remains for the services to effectively operate in concert to win the nations wars. One technology to aid in this endeavor will be explored in this thesis, the Adaptive Joint C4ISR Node (AJCN).

C. RESEARCH QUESTIONS

The intent of the following research questions is to frame the conduct of the information gathering process and to gain insight into the issues that affect the AJCN's employment during operations.

1. Given a scenario--How many AJCN nodes are required?
2. What are the critical vulnerabilities to the AJCN and its capabilities?
3. What can be done to mitigate the threats to the AJCN?
4. Which levels of AJCN nodes most effect operations?
5. What can be done to mitigate friendly fratricide?

D. METHODOLOGY

The focus of this thesis is on evaluating the impact of the AJCN as an enhanced information warfare capability in a wargame scenario. Research will be conducted using two methods.

The first method incorporated wargaming using both the tabletop method with a situation map, and a constructive simulation in the "human in the loop" mode. The tabletop method provided an "open" wargame in that all the players had "essentially free access to all available information about each side's forces and capabilities (but not about plans!)." [Ref. 7, 175] The constructive simulation provided a "closed" wargame experience to "better simulate the 'fog of war' by introducing limits on the information available to the players." [Ref. 7, 175] The Wargaming course taught at the Naval Postgraduate School provided the platform for the wargame.

The wargame class was divided into two teams, the friendly and opposing forces teams. Each team had a designated commander while the rest of the team members were given various roles as primary staff officers on their team. The teams were then issued their mission, upon which they conducted their mission analysis.

During mission analysis, the commander and the staff draw together all available intelligence and information, orient it to the assigned mission, develop an understanding of the tasks to be accomplished, and formulate a rough concept of how to best accomplish those tasks. The result is an initial statement of the commander's intent and the receipt of the commander's planning guidance that focuses the remainder of the planning process.

Building on the knowledge gained through mission analysis, the commander and staff develop a concept for carrying out the required tasks that embodies the commander's intent. This concept, or Course of Action (COA), encompasses general schemes for the execution of maneuver, fires, logistics, and other supporting functions that are necessary for the successful conduct of the mission. The staff develops several COAs based on the commander's intent and planning guidance.

After they are developed, the COAs are analyzed and compared in an effort to identify the best COA and prepare concept of operations needed to implement that COA. The staff conducted a detailed analysis of each COA, and each principal staff officer prepared a formal estimate of supportability. The COAs were then wargamed to predict the action, reaction, and counteraction dynamics of each COA. At the conclusion of this "open" forum wargame, a COA was chosen for the "closed" wargame.

The "friendly" and "enemy" COAs were then executed in the Joint Conflict and Tactical Simulation (JCATS). The students controlled the movement of their units and were able to "see" only the enemy that their reconnaissance and surveillance systems were able to see on the digital battlefield, thus epitomizing the "closed" mode of wargaming.

The second method involved using the "closed loop" capability of POA2 to conduct several iterations of a combat scenario with varying levels of AJCN incorporation. This iterative method allowed the evaluation of combat outcomes to offer insight as to the most beneficial employment of the AJCN system in a given scenario. Although the scenario is not universal in application across the broad spectrum of possible combat situations, it provides a possible baseline upon which to build further analytic calculations for appropriate levels of AJCN employment.

Using both wargaming and simulation allows the insight gained to be more balanced vice the use of only one method. It is not just the employment of the system that is of interest, but also how the combatants (i.e. staff) seek to employ

the system given their particular predispositions and experience. The insights gained from both methods individually and collectively are described in detail in the conclusion chapter of this thesis.

Insights gleaned from the first method arise primarily from the observation of the staff's employment of the system vice more quantitative means of analysis. However, the second method relies completely on quantitative analysis to gain insight into the AJCN's employment based on the nature of the method itself. For the second method, Measures of Effectiveness (MOEs) are required to obtain a proper perspective on the quantitative results.

The Measures of Effectiveness used in evaluating the AJCN are based on the AJCN capabilities as modeled in POA2. The following MOEs are used for the analysis of the closed loop runs:

MOE 1: Force Exchange Ratio

$$\frac{\Delta FriendlyForce}{\Delta EnemyForce}$$

We desire a minimal Force Exchange Ratio which relates a greater situational awareness provided or not provided by the AJCN through that ability for friendly forces to engage more enemy targets and thereby decrease the enemy's effectiveness through attrition.

Data Requirements: Friendly kill count and enemy kill count.

MOE 2: Fractional Exchange Ratio (FER):

$$\frac{\Delta FriendlyForce / FriendlyForce}{\Delta EnemyForce / EnemyForce}$$

We desire a FER of close to 0. This relates that friendly forces incurred fewer proportional casualties than the enemy force.

Data Requirements: Friendly kill count, initial friendly force level, enemy kill count and initial enemy force level.

MOE 3: Friendly Kill Ratio:

$$\frac{\textit{FriendlyKilledByFriendly}}{\textit{FriendlyForceLevel}}$$

We desire minimal Friendly Kill Ratio relating AJCN's success in disseminating friendly position data.

Data Requirements: Count of friendly forces killed by friendly forces and initial friendly force Level.

MOE 4: Acquisition Rate:

$$\frac{\textit{EnemyForcesObservedbyFriendlyForces}}{\textit{EnemyForceLevel}}$$

We desire maximum proportion of enemy forces "seen" by all blue forces to allow friendly forces greater situational awareness.

Data Requirements: Number of enemy entities "seen" by all blue forces and total number of enemy entities on battlefield.

MOE 5: Survivability:

$$\frac{\textit{\#AJCNsDestroyed}}{\textit{\#AJCNsFielded}}$$

We desire minimal number of AJCNs destroyed relating successful deployment, utilization, and recovery of the AJCN systems.

Data Requirements: Number of AJCNs destroyed by what type of enemy system and initial number of AJCN fielded for mission.

E. THESIS OBJECTIVES

The primary purpose of this thesis is to gain insight on an emerging platform as an enabler for network centric warfare. Furthermore, we intend to assist in the development of the CONOPS for this system. The capabilities of the system will be represented in wargaming and simulations to discover their level of impact on mission success.

F. THESIS SCOPE

This thesis will consider the primary capabilities provided by the AJCN in their delivered state. The goal of this thesis requires only that the AJCN's capabilities, described in the AJCN Operational Concept (OPCON) (ACTD Version 1.2) [Ref. 8], be modeled to observe their influence on the outcome of a battle. The effect of the AJCN's capabilities to improve or detract from the friendly force's performance will provide insights into the effective operational use of the AJCN.

II. ADAPTIVE JOINT C4ISR NODE (AJCN)

A. ADAPTIVE JOINT C4ISR NODE (AJCN)

The Adaptive Joint C4ISR node is being developed by a BAE Systems-led team of Department of Defense contractors. The system is comprised of two parts, the Mission Payload Segment (MPS) and the Control and Reporting Segment (CRS) software. The MPS will be carried by a variety of manned and unmanned airborne platforms. The CRS software, which controls the employment of the MPS, will be installed on various existing ground, air, and sea-based computer workstations. The AJCN provides four mission capabilities: Communications bridging, relay and reach back; SIGINT; Electronic Warfare (EW); and Information Operations (IO). "The four mission capabilities will synergistically work together on a single scaleable payload to provide a unique and much needed capability for military commanders at tactical and operational echelons with a reach back capability to strategic assets." [Ref. 2]

1. Communications

The AJCN supports three communication functional capabilities; range extension, waveform bridging, and reach back.

a. Range Extension

Range extension is the capability for like radio systems to communicate beyond the designed range. The system will receive a transmission on one frequency and relay the content to the destination radio system on a different frequency. This capability currently exists within the DoD services, but is primarily performed by ground-based systems that rely on the choice of high elevation terrain that provides the best Line of Sight (LOS) to the supported units. Emplacement of ground based communication relay stations is a time consuming and security driven process that does not lend itself to the flexibility required of a quickly moving ground force. These stations are normally emplaced prior to friendly forward movement on the battlefield and are stationed as far forward as is feasible given the enemy's posture. Thus, their coverage is ideal for the initial phases of friendly ground force movement, but is quickly

diminished once ground forces have moved any considerable distance. Once the relay stations' utility is consummated, the teardown and relocation process is laborious and time consuming and does not allow for the continuous coverage provided by an airborne relay platform.

b. Waveform Bridging

Waveform Bridging is defined as the ability to effectively receive information transmitted in one wave format (waveform) and retransmit the information in another waveform. There is currently no system used within the DoD that provides this capability. The long-term solution to this problem resides within the Joint Tactical Radio System (JTRS) program, which "will provide reliable multi-channel voice, data, imagery, and video communications-and eliminate communications problems caused by "stovepipe" legacy systems." [Ref. 17] However, until the program is fully deployed and fielded, the need for waveform bridging capabilities remains key to mission success for both military applications and combined civilian-military operations, like those conducted in support of Homeland Defense operations or exercises. The scenario depicted in Figure 1 demonstrates pictorially the AJCN's capability to "translate" between a cell phone's, SINCGARS, AM, and FM waveforms. The functionality enables interservice, intraservice, and interagency communications to accommodate a full spectrum of operations.

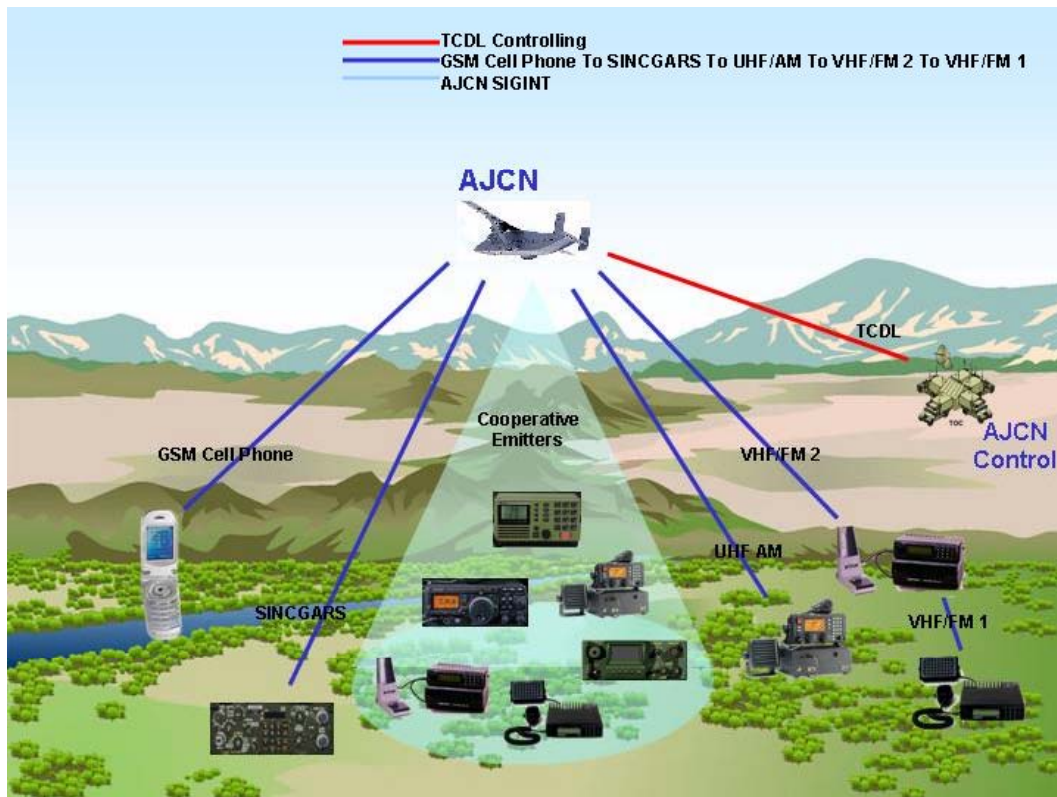


Figure 1. Pictorial representation of AJCN performing Waveform Bridging and SIGINT Missions

c. *Reach Back*

Reach Back is defined as "the ability to communicate with someone who is outside the theatre of operations" [Ref. 2]. Currently, reach back capabilities are limited to Special Operation Forces and high echelon unit headquarters using secure satellite links and cutting edge technologies. The system will provide the ability for linkage to be available to more levels within the chain of command, affording more flexibility to the commanders at all levels. This will be accomplished through a CRS-provided network interface (Secure Internet Protocol Router Network (SIPRNET) or Joint Worldwide Intelligence Communications System (JWICS)) that will establish connectivity with higher headquarters elements and provide a secure means of transmitting voice, data, and video formats.

2. Signal Intelligence (SIGINT)

The AJCN's suite of SIGINT functionality covers a large range of capabilities. These capabilities include: signal detection, signal demodulation, signal identification, Direction Finding (DF), emitter location, and electronic mapping of the battlefield. Signal detection is the ability of a signal receiver to sense and capture the emitted signal. Signal identification is the ability to analyze the detected signal and identify its frequency. The signal demodulation takes that signal and recovers the "content" to some analyzable format. The Direction Finding capability performs a reverse trajectory operation on the incoming signal to determine the direction from the receiver to the emitter. The direction finding capability complements the ability to determine the emitter location using a triangulation calculation using several samples of the incoming signal direction over a period of time. All these functions work together to generate an electronic mapping of the battlefield portraying the friendly and enemy emitters on the ground.

3. Electronic Warfare (EW)

The AJCN will contain the capability to jam enemy radio frequencies. The CRS operator can either manually select the frequency and jamming type or set the system to automatically jam when energy is detected on a pre-programmed set of frequencies (Jam on Energy). The AJCN is capable of continuously jamming a single signal continuously or jamming multiple targets by timesharing the jamming at a predetermined rate. [Ref. 2]

4. Information Operations (IO)

IO capabilities include support of Radio Broadcast operations and Computer Network Attack (CNA). Radio Broadcast operations include the broadcast or re-broadcast of FM signals in support of Psychological Operations (PSYOPS) missions. The CNA allows for the intercept and attack of "otherwise-inaccessible wired targets by entering the network through a wireless node." This accommodates an attack strategy of injecting deceptive messages into a victim's data network [Ref. 2]

The capabilities listed above are not all inclusive with respect to what the AJCN's full suite of functions will contain in its final configuration. These merely relate a portion of the capabilities that are being exercised as part of the Advanced Concept Technology Demonstration (ACTD).

Adaptive Joint C⁴ISR Node Multi-Mission Capabilities

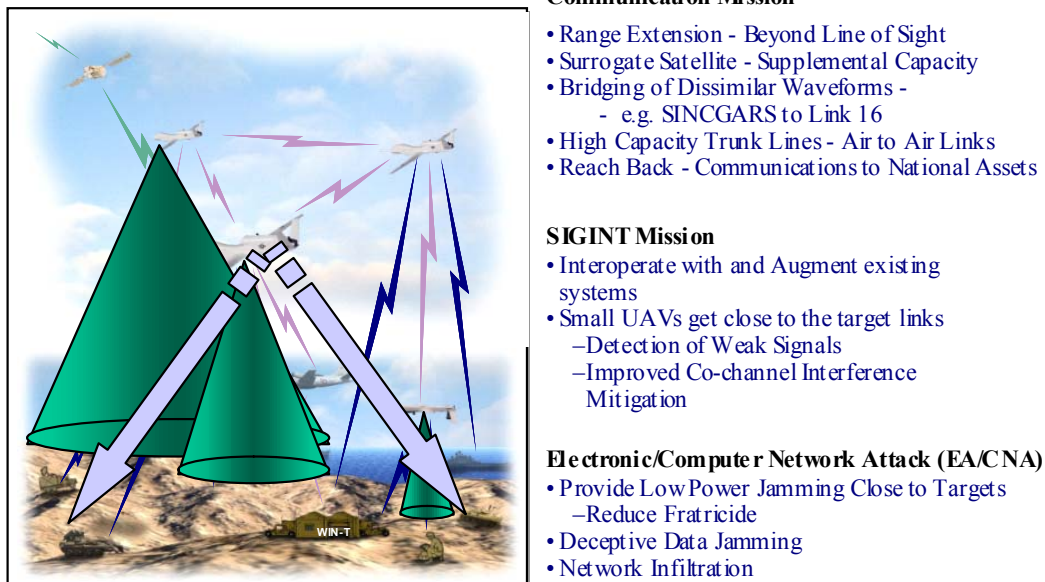


Figure 2. AJCN Mission Summary

B. AJCN PLATFORMS

For the purpose of this thesis, three platforms used to field the AJCN MPS will be evaluated during this study. The AJCN MPS is scaleable to adapt to a variety of platforms, both aerial and ground-based. The capability of the AJCN MPS is based on the platform upon which it is mounted, primarily due to the power supply capabilities of the platform and the weight constraints imposed by the platform itself. The purpose of employing multiple "tiers" of coverage is to provide the capability of a "self-healing" array of coverage for the supported units. This redundancy not only provides for fluid coverage on the occasion of loss of a platform but also allows for greater intercommunication capabilities for

units far beyond conventional radio-based communication systems. Following is a basic description of each of the aerial platforms ordered by their operating altitude, from least to greatest.

1. RQ-5/Hunter

The RQ-5/Hunter UAV provides the foundational level of support for this study. The Hunter has an operating ceiling of 15,000 feet and a maximum speed of 106 knots with an endurance of 11.6 hours. It has a payload capacity of 50lbs. Given the MPS weight restrictions and the altitude; the radius of coverage for the AJCN on the Hunter is 50 miles. [Ref. 18] The Office of the Secretary of Defense conducted an Unmanned Aerial Vehicle Reliability Study which revealed that the Hunter has a reliability rating of .82 and a mishap rate of 16 per 100,000 hours. [Ref. 19] The Hunter operates at the lowest altitude and will therefore comprise the lowest tier of coverage.



Figure 3. Hunter UAV

2. KC-135 Stratotanker

The KC-135 Stratotanker is the second tier platform used for this study. At an operating altitude of 25,000 feet and a speed of 530mph it can range 1,500 miles if conducting refueling operations and 11,000 miles if it is conducting a "ferry" mission. The AJCN MPS mounted on this platform provides a 90-mile radius of coverage. The marked advantages of this platform over the other two examined here is the increased power supply provided by the aircraft, its increased ability of range, and greater time of remaining aloft.



Figure 4. KC-135 Stratotanker

3. Global Hawk

The Global Hawk UAV provides the platform for the high-tier AJCN MPS. It has an operating ceiling of 65,000 feet and maximum cruising speed of 340 knots. The MPS mounted on the Global Hawk can provide a 150-mile radius of coverage. As of May 2003, the Global Hawk has an accident rate of 167.7 per

100,000 flight hours. [Ref. 22] The Global Hawk has a "ferry" range of 15,500 miles and an operating endurance of 36 hours. This UAV comprises the top-tier of coverage for this analysis.



Figure 5. Global Hawk UAV

III. SCENARIO

The scenario for the wargame took place in the South China Sea. This region of the world was chosen for the wargame because of its potential military threat. This threat is well documented and presented in the United States Department of Defense FY04 Report to Congress on Peoples Republic of China Military Power.

A. BACKGROUND

The South China Sea is a semi-enclosed sea that covers an area of 3.5 million square kilometers (sq km). It is located between the Pacific and the Indian Ocean, thus providing a critical link to the continents of Asia, Africa, Europe and Australia. States with borders on the sea (clockwise from north) include: the People's Republic of China, Republic of China (Taiwan), the Philippines, Malaysia, Brunei, Indonesia, Singapore, Thailand, Cambodia, and Vietnam. The South China Sea Islands is an archipelago of over 250 around 1-km² islands, atolls, cays, shoals, reefs, and sandbars, most of which have no indigenous people. The Islands are subdivided into four sub-archipelagos (listed by area size):

- * The Spratly Islands (Nansha Islands)
- * The Macclesfield Islands (Zhongsha Islands)
- * The Paracel Islands (Xisha Islands)
- * The Pratas Islands (Dongsha Islands)

Because of the economic, military, and transportation importance, the control, especially of the Spratlys, has been in dispute by China and several Southeast Asian countries, especially Vietnam, in the mid-20th century onwards.

It is one of the busiest maritime shipping routes and it witnesses one-fourth of the world's crude oil and oil products transported through its waters. The South China Sea is rich in natural resources. There are minerals, natural gas, and oil deposits on the islands and the seafloor. For this reason, at the end of the

1970's, countries around the South China Sea area declared their sovereignties over all or part, one after another, and then the dispute emerged. In 1995, when the UN Convention on the Law of the Sea (UNCLOS III) came into effect, this dispute suddenly became a hot topic. Today, the South China Sea, which includes the Paracel and Spratly Archipelagos and the Natuna Island group, is the most volatile flashpoint in Southeast Asia. Mainland China, Taiwan, Vietnam, Malaysia, the Philippines and Brunei all claim control over part or the entire archipelago.

The sensitivity and instability of relations in the South China Sea is evident when considering recent activities by China. On July 17, 2004, the PRC began a week-long war game simulating an invasion of Taiwan. The exercise was conducted on Dongshan Island and involved over 18,000 troops, sea and air assets. [Ref. 23]

B. WARGAME SCENARIO

The scenario used for the wargame takes place in the year 2016. In this scenario, China has continued a rapid economic growth and used the funds from its growing economy to enhance education, social programs, and military forces. The military funding focused on strategic and naval forces capable of establishing larger force projection range from its shores. The scenario depicts a treaty being signed by Taiwan and China to establish unification by the year 2018.

Control of the South China Sea was seen as a strategic necessity by the PRC (Peoples Republic of China). The off shore oil reserves were claimed as a result of the increased naval forces and consequently in 2015 China publicly claimed hegemony over the entire South China Sea. Later the same year, the PLA (Peoples Liberation Army) and the PRC Navy reinforced its presence in the Spratly Islands. A number of military enhancements were made on the islands to include runways, pier and maintenance facilities, Air Defense sites, and surface to surface ballistic missile sites. These actions were condemned by the United States, Philippines, Vietnam, Indonesia, Malaysia, Singapore, and Japan but no consensus on a response could be mustered. A hasty common defense

treaty from the countries of Indonesia, Malaysia and the Philippines was established as a response for this aggressive behavior, but was disregarded by China.

Throughout 2015 China continued to build on its military presence in the South China Sea despite numerous protests. Tensions climaxed in 2016 when a Philippine jet aircraft strafed a Chinese destroyer during live fire exercises two miles off the Palawan Islands coast. The incident resulted in the loss of ten Chinese sailors. The destroyer returned fire but failed to hit the Philippine aircraft.

This incident spawned a new agenda for the Chinese. The PRC claimed that they now had a reason to establish a “safety” perimeter around the South China Sea. The Chinese saw that establishing a perimeter required the invasion of Kepulalian Natuna (Indonesia). The island was taken by force and was controlled by a division of PLA supported by an air defense regiment, ten surface to surface missile batteries, and ten shore to ship missile batteries. Nations within the South China Sea region were threatened to disregard and not react to the actions taken against Kepulalian Natuna. Doing so would result in the invasion of Palawan. To reinforce this threat the PRC Navy set up quarantine on Puerto Princesa port, Palawan. The PRC government was now in position to dictate a new order in the South China Sea region and did so with a treaty between Philippines and Indonesia. The treaty resulted in the New Era of South China Sea Cooperation among perimeter nations.

The United States and other supporting nations condemned the actions by China and submitted a joint United Nations resolution to establish sanctions against the PRC. The resolution did not stand and was vetoed by the Security Council. This led the United States National Command Authority, through the Secretary of Defense, to establish a Combined JTF (Joint Task Force) with Indonesia, Philippines, Singapore, and Australia. The mission of the JTF was to prepare alternative courses of action to deter Chinese aggression and protect Philippine and Indonesian sovereignty. Additionally, the CJTF commander should be prepared to repel invasion of Palawan Island with follow-up operations

to re-establish Indonesian sovereignty over Kepulauan Natuna without any strikes of the Chinese mainland or Taiwan.

C. ANALYSIS SCENARIO

The analytical section of this thesis focused a portion of the scenario used for the wargame. The actual wargame analysis covered several weeks time and the entire South China Sea area. The constructive simulation conducted with POA 2 is focused on a decisive battle on the island of Palawan, specifically the battle for Puerto Princessa. The island of Palawan's strategic strength is its main sea port and its airport. Both of these are located on the southern side of the island in the vicinity of the city of Puerto Princessa. The US forces understood that a military invasion of the island of Palawan would require immediate control of these strategic points and focused their invasion on gaining an immediate foothold in and around Puerto Princessa.

The scenario begins with Chinese forces emplacing slightly over a brigade's worth of infantry forces and a company size element of armor forces around the northern outskirts of the city of Puerto Princessa. Additional infantry forces were located within the city and around the port. The entire city (the port and its surrounding waters) and the airport are all covered by artillery support from over a battalion's worth of artillery and an air defense battery that has surface to air missiles that can range over the entire island. Chinese forces exist elsewhere on the island but are not involved in this fight.

The US forces have established a foothold in their effort to gain control of the island and its strategic assets. It was determined that a direct amphibious assault near or on the port of Puerto Princessa would be too costly in both personnel and equipment. In an effort to minimize casualties the US forces conducted amphibious operations on the south coast of the island about 20 kilometers to the west of Puerto Princessa, in the vicinity of the city of Inagawan. A rapidly moving Marine task force consisting of 2 battalions of wheeled infantry, a company size tank element, with artillery and air defense batteries in support, executed this mission. An additional medium range rocket unit was placed at on the northern coast of the island about 30 kilometers northwest of Puerto

Princessa. The importance of this unit will be revealed when the AJCN is incorporated in the scenario. A U.S. aircraft carrier located off the southern coast of Palawan provided Close Air Support (CAS). Two F-18 Super Hornets were sortied from the carrier to provide continuous coverage of the Marine task force.

The US forces begin movement eastward towards Puerto Princessa upon establishment of a beachhead. A tank company leads the forces with the infantry forces following. The artillery and air defense forces bound forward in order to maintain their support to the combat units. Due to the very restricted terrain, the routes initially used by the US forces are along the coastal road network on the southern edge of Palawan. This scenario will be conducted with various quantities of AJCN systems to evaluate their impact on the battle outcome.

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IV. WARGAME

A. WHAT IS A WARGAME?

"A wargame is a warfare model or simulation whose operation does not involve the activities of actual military forces, and whose sequence of events affects and is, in turn, affected by the decisions made by players representing the opposite sides." [Ref. 7, 164] As stated by Perla, "ultimately, the goal of all war game design is communication." [Ref. 7, 185] This communication aims to show the analyst, commander, or staff officer a possible cause and effect relationship between the battlefield systems and the course of action used to employ those systems.

A wargame is comprised of several elements, which build upon one another to provide the user an educational experience. The most important element is human decision making. This facet of wargaming separates it from strict simulation, where "decisions" are based on preset algorithms in a computer program. Other essential elements of a "good wargame" are: objectives, a scenario, a database, models, rules, players, and analysis. [Ref. 7, 165] These elements generate the platform for the players to achieve their goal for the wargame.

The use of wargames spans a wide spectrum. [Ref. 7, 165] Wargames can be used for education, entertainment, to exercise detailed war plans prior to a deployment, or to exercise new systems to identify weaknesses in design in an effort to compliment the design process. This thesis aims to use the later employment of a wargame as the AJCN is employed in a Joint Force scenario to generate insight into its employment as a combat multiplier and aid in the development of the AJCN's CONOPS.

B. USE OF WARGAMING AS A CONOPS DEVELOPMENT TOOL

Generating an accurate picture of the battlefield is essential to the success of an operation. This thought is echoed by Sun Tzu, who describes this truth in the following manner,

...to estimate the enemy situation and to calculate distances and the degree of difficulty of the terrain so as to control victory are virtues of the superior general. He who fights with full knowledge of these factors is certain to win; he who does not will surely be defeated. [Ref. 9]

The development of a concept of operations for a system's or unit's employment using wargaming parallels the use of wargaming by battle staffs to develop plans and orders. United States Army Field Manual 101-5, Staff Organization and Operations, Final Draft 1996, defines wargaming as;

...a disciplined process with rules and steps which attempts to visualize the flow of a battle, given friendly dispositions, strengths, and weaknesses; enemy assets and probable COAs; and the characteristics of area of operations. [Ref. 10]

Here we seek to visualize the employment of the AJCN and its effects on the outcome of the battle. Several aspects of a wargame require attention and care to ensure that conclusions drawn from the wargame are taken in context. Perla addresses several of these issues in his book, The Art of Wargaming:

...wargaming is not analysis...It is not a technique for producing a rigorous, quantitative or logical dissection of a problem or for defining precise measures of effectiveness by which to compare alternative solutions. A wargame is not duplicable. A wargame is a warfare model whose sequence of events is affected by the decisions made by players representing the opposing sides. [Ref. 7, 164]

The use of wargame outputs is quite similar between the battle staff generating an Operational Plant (OPLAN) and the development of a CONOPS. Both use the insights gleaned from the wargame as a foundation for planning the employment of forces or systems. The characteristics of a wargame, as noted above, must be considered with great regard as plans or CONOPS are developed. The wargame represents a snapshot in time, with a specific set of individuals with particular backgrounds placed in a particular scenario resulting in specific decisions that are unrepeatable. The output of the wargame must be taken for what it is and not a quantifiable resource upon which to base significant

decisions, but rather to offer an analytical check on decisions made or decisions in the process of being made.

The most appropriate term for the output of a wargame is "insight". "Insight" gained through a wargame takes on the form of any of the following:

- ☐ Effective use of a unit/system in a particular situation
- ☐ Actions of the enemy not previously considered
- ☐ Plausible friendly actions not previously considered
- ☐ Logistical issues connected to the plan or its branches
- ☐ Requirements of support from higher echelons not previously addressed
- ☐ Redundancy of effort (ability to shift forces to maximize their effect on the enemy) and many others

This thesis used a wargame to gain insight into the employment of the AJCN and generate insight on its employment from the perspective of how the battle staff employs the AJCN and how the enemy reacts to the system. These insights are presented in an Issue/Recommendation format in a later section.

C. WARGAME EXECUTION

The wargame was conducted in the context of the Wargaming course, OA4604, offered at the Naval Postgraduate School, during the Fall Quarter 2003. The primary objective for the Wargaming course's wargame was the exposure of mid-grade officers to the use of wargaming as a tool used in the Military Decision Making Process.

Officers from three services and five nations, Army, Navy, and Marine, were selected to take on the role of the various staff positions normally associated with a Joint Planning Staff. Staff positions were filled for both the "friendly" and "enemy" forces. The staffs separated to generate their respective courses of actions, which were wargamed in an "open" forum, as described in the Methodology section, using analog techniques to generate combat losses.

Upon the finalization of the two sides' courses of action, the two forces were arrayed in the digital constructive simulation platform, JCATS, for a "closed" wargame.

JCATS was used as a platform to accommodate adjudication of the interactions of the two opposing forces. There were no "automatic" algorithms engaged that would allow any of the forces to move without being directed by the players. The officers on each team were trained on how to employ their forces in JCATS. The number of students in the course required that most of the "staff" take on the additional role of "pucker", while the two commanders and their respective executive officers were able to track the battle from their maps.

The "simulation center" provided separate "rooms" for the two sides to conduct their operations in isolation. Numerous computer terminals were available in each room, controlling a portion of the friendly or enemy forces respectively. Terminal operators could only "see" the units that they controlled and the units, friendly or enemy, that his combat systems "saw" based on their individual line of sight or radar/sensor capability. The "friendly" and "enemy" commanders each had an area within their respective rooms to maintain and update their situational map to facilitate making decisions based on the developing situation.

The workstation controllers were assigned to their workstations, which controlled a set portion of the friendly or enemy forces. Forces were arrayed based on their planned positions from the course of action decided upon by the respective sides. Once the forces were arrayed the game-clock was started and the battle ensued. The insights gained during this wargame were not quantitative with respect to the number of enemy or friendly killed, but more on the conduct of the commanders and their staffs and how they employed the AJCN and their reactions to the situational awareness that it provided. The following section gives more detail to the JCATS model itself.

V. SIMULATION

A. WHAT IS A CONSTRUCTIVE SIMULATION?

The definition of simulation is divided into three categories. They are defined as follows by the Defense Modeling and Simulation Office (DMSO):

Live, Virtual, and Constructive Simulation

A broadly used taxonomy for classifying simulation types, the categorization of simulation into live, virtual, and constructive, is problematic because there is no clear division between these categories. The degree of human participation in the simulation is infinitely variable, as is the degree of equipment realism. The categorization of simulations also suffers by excluding a category for simulated people working real equipment (e.g., smart vehicles).

Live Simulation: A simulation involving real people operating real systems.

Virtual Simulation: A simulation involving real people operating simulated systems. Virtual simulations inject human-in-the-loop in a central role by exercising motor control skills (e.g., flying an airplane), decision skills (e.g., committing fire control resources to action), or communication skills (e.g., as members of a C4I team).

Constructive Model or Simulation: Models and simulations that involve simulated people operating simulated systems. Real people stimulate (make inputs) to such simulations, but are not involved in determining the outcomes. [Ref. 11 and Ref. 12] The definition of simulation, as defined by DMSO, also supports the Joint Concept of Operation as set forth by Joint Capabilities and Integration Development System (JCIDS). All three types of simulations can be used in CONOPS development. The decision on the type of simulation to be used is driven by the mission, the requirements, and the technology available. For the purposes set forth in this thesis we will use constructive simulations to gain insight into the development of CONOPS and serve as a basis for our analysis.

B. USE OF SIMULATION AS A CONOPS DEVELOPMENT TOOL

Designing combat systems for the 21st Century is becoming increasingly complex. They are characterized by including much more information and serving many more purposes than previous systems. Additionally, these combat systems are no longer viewed as final designs when issued to the intended user. Rather, they are required to evolve and adapt to ever-changing battlefield requirements. This shift towards designing systems that can be evolved to the future battlefield requires a non-traditional approach to establishing system requirements. This chapter discusses how simulations can aid in CONOPS development.

The term CONOPS is used throughout industry and the military. The definitions vary for the specific application. Only within the armed forces are the definitions uniform as to what exactly is a CONOPS.

Various Definitions of Concept of Operations:

US Dept of Homeland Security: Document detailing the method, act, process, or effect of using an Information System. [Ref. 29]

US Army: A graphic, verbal, or written statement in broad outline that gives an overall picture of a commander's assumptions or intent in regard to an operation or series of operations; includes at a minimum the scheme of maneuver and the fire support plan. The concept of operations is embodied in campaign plans and operation plans particularly when the plans cover a series of connected operations to be carried out simultaneously or in succession. It is described in sufficient detail for the staff and subordinate commanders to understand what they are to do and how to fight the battle without further instructions. [Ref. 30]

US Navy: A verbal or graphic statement, in broad outline, of a commander's assumptions or intent in regard to an operation or series of operations. The concept of operations frequently is embodied in campaign plans and operation plans; in the latter case, particularly when the plans cover a series of connected operations to be carried out simultaneously or in succession. The

concept is designed to give an overall picture of the operation. It is included primarily for additional clarity of purpose. Also called a commanders concept. [Ref. 13]

The definitions presented in here do not clearly match the meaning of CONOPS as it applies to the representation of new and evolving systems in modeling and simulation. For the uses of modeling and simulation a CONOPS is best described as a narrative discussion of how a system is intended to operate. In its intended environment it is written from multiple perspectives and captures all aspects of the systems operation. Additionally, it captures both short-term and long-term operational aspects of systems in a joint environment. A successful system CONOPS is one that can be used to quickly provide warfighters with a comprehensive overview of the system and how it functions in a joint environment.

CONOPS as it is defined here supports the Joint Concept of Operations set forth in JCIDS. It provides a way to describe how all components work together in a joint environment.

Using simulations to develop CONOPS in the military dates back to the cold war, during this era the DoD began using computer simulations to analyze course of action development. Computer simulations such as the Concepts Evaluation Model (CEM) were utilized to gain insight towards CONOPS development for possible NATO-Warsaw Pact combat in Europe (Warfare Modeling, MORS). Since the early 1990's simulations have been widely used in the development of both CONOPS and new systems. During this time frame technology has evolved at such a rapid pace that the DoD realigned many of it's Model and Simulation Organizations to better support the modern battlefield requirements. [Ref. 14]

The DoD has recently put forth a great deal of effort to integrate CONOPS development and simulations. In 1997 a major DOD initiative designed to improve the acquisition process was set forth. This process is called Simulation, Test and Evaluation Process (STEP). STEP integrated Modeling and Simulation

(M&S) with Test and Evaluation (T&E). The process is intended to provide early and continuous information to the joint military worth of a system so that the total life cycle is more effective and efficient. All this is to be done through incorporating M&S with T&E. [Ref. 15]

This process provided a catalyst for incorporating simulations into systems acquisitions. Since STEP, additional efforts have been set forth to further enhance system development in the joint military. These efforts further support the use of simulations as a tool for joint systems development.

As the joint force becomes more integrated and interdependent, a coordinated process is required to define how the joint force operates and how new capabilities are identified and developed. JCIDS establishes new methods for generating system requirements. JCIDS implements an integrated, collaborative process, based on top-level strategic direction, to guide development of new capabilities through changes in doctrine, organization, material, training & education, leadership, personnel, and/or facilities. The difference from JCIDS and the past processes is in the requirements development structure. The previous methods for system requirements allowed systems to be developed in isolated environments (i.e. Army, Navy, etc) and subsequently deconflicted at the joint level. The JCIDS methodology flows from a top down architecture or top down requirements born at joint level. This top down process translates into the Joint Concept of Operations. An implication of this process is that simulations once conducted in the T&E stages of systems acquisition will now be required at the beginning stages of acquisition. [Ref. 16]

The Joint Concept of Operations establishes processes for component services to plan and develop systems to work in collaboration on the Joint Battlefield Environment. A method for doing this is Concept of Operations development using simulation.

No step-by-step method for developing CONOPS through Simulation is set as a standard throughout any of the DoD. Based on Test and Evaluation procedures, acquisition procedures, and examining previous CONOPS

development procedures we have diagrammed how a CONOPS development using a constructive simulation might look. This diagram (Figure 6) describes where simulations may best be used in the process of the development. The Mission Analysis uses the Mission Tasks derived from the training requirements and the system objectives derived from the Operational Requirements Document (ORD) and the user's Concept of Operations to define the total set of requirements for the system. Through the integration of the Mission Tasks, Training Requirements and the Engineering Requirements a Constructive Simulation Model is built to provide insight and helps define the Detailed Requirements to the CONOPS.

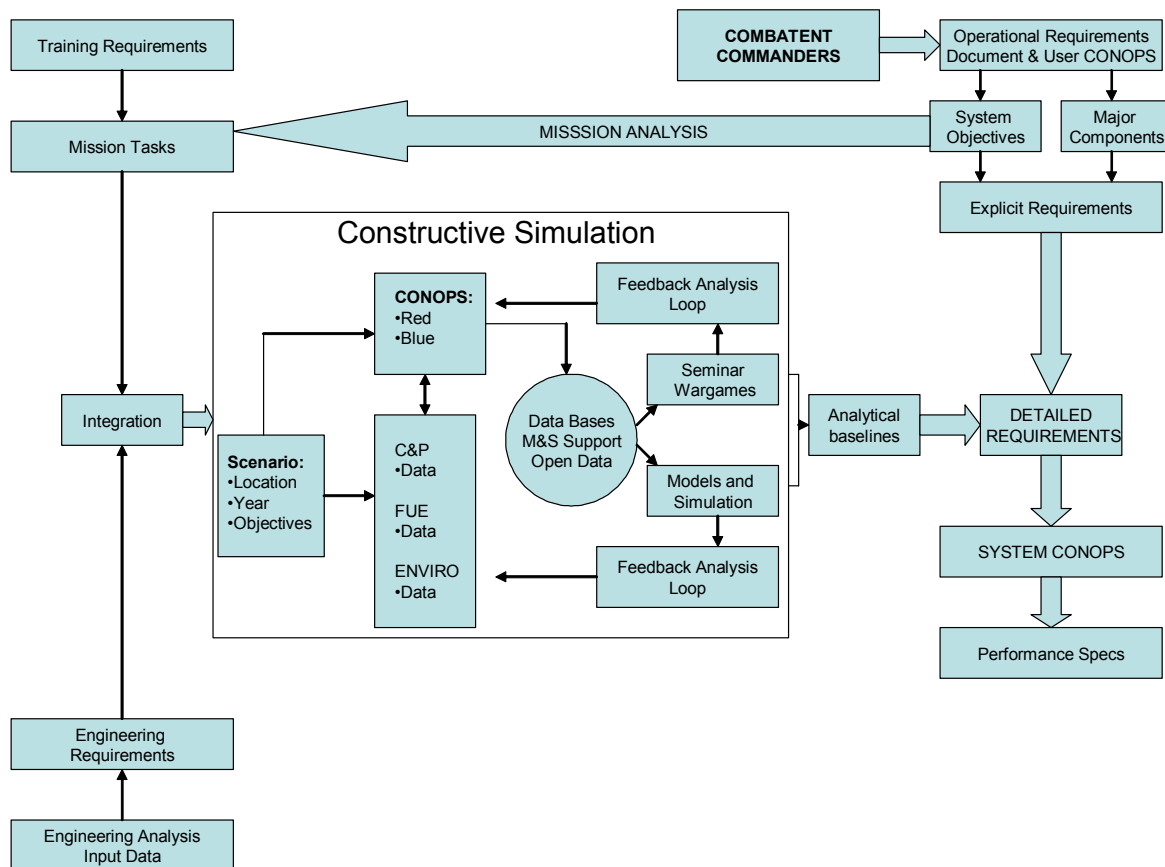


Figure 6. Proposed CONOPS Development Methodology

The methodology put forth in Figure 5 is based a model put forth by Dr. Jim Stevens, Director, Joint Data Support, OSD PA&E. It is not to be thought of as a total solution, but as a starting point for developing an approved methodology that would support development and acquisitions procedures as put forth in the Joint Concept of Operations.

C. JCATS MODEL

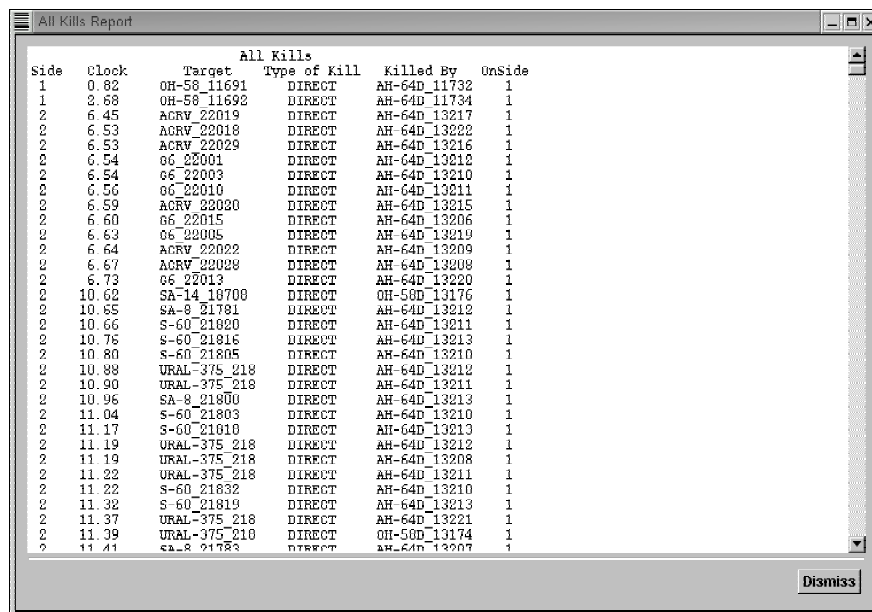
The Joint Conflict and Tactical Simulation (JCATS) is a computer-based combat simulation program developed by the Lawrence Livermore National Laboratory. "The program is currently used for training both individuals and command staffs in tactics and deployment of resources, analyzing the effectiveness of weapons and different force structures, and planning and rehearsing missions." [Ref. 20]

JCATS is a constructive simulation that can accommodate the simulation of a broad spectrum of operations. The two main audiences of this model are the training and analytical communities. The model accommodates both audiences through a number of tools that provide the user with ability to generate and execute a scenario with a user-defined level of detail. This thesis aimed to use the model in both modes, for training and analysis.

JCATS provides the trainer with an interactive model that allows the users to control the actions of every entity on the simulated battlefield. This "human-in-the loop" mode of execution allows for the adjustment of plans based on "enemy" actions and the interjection of more "realistic" actions of entities upon making contact with "enemy" units. Entities can be aggregated into "unit" sized elements to allow for ease of "road march" type movement and can then be deaggregated upon nearing contact with "enemy" units to allow for the manipulation of lower level units to engage the "enemy" in a more tactical manner instead of acting as one large unit in a formation. This flexibility the level of scenario detail provides the capability to accommodate training audiences of various levels in an organization. Audiences can range from an individual attempting to gain insight

into the best way to enter a building given a set enemy disposition to a Brigade level staff needing to exercise their planning process or generate insights during a Course of Action Analysis.

JCATS also provides the analyst with a platform to test new equipment, try new methods of employing units, and answer a myriad of other questions. Once a scenario is built, the analyst has the capability to "program" the movements of all the entities on the battlefield to accommodate a "closed loop run." The model can collect many types of data during the runs for later analysis. Multiple runs may be conducted using the "batch run" option to execute any specified number of runs of the scenario to generate the data required for statistical analysis. Upon completion of the runs, the data can be viewed with the Analyst Work Station (AWS). The AWS provides a means to view the collected data in either its raw or summary format and a selection of graphical representations of the data. Below are a sample of reports that are available to the analyst.



Side	Clock	Target	Type of Kill	Killed By	OnSide
1	0.82	OH-58 11691	DIRECT	AH-64D 11732	1
1	2.68	OH-58 11692	DIRECT	AH-64D 11734	1
2	6.45	ACRV 22019	DIRECT	AH-64D 13217	1
2	6.53	ACRV 22018	DIRECT	AH-64D 13222	1
2	6.53	ACRV 22029	DIRECT	AH-64D 13216	1
2	6.54	06 22001	DIRECT	AH-64D 13212	1
2	6.54	06 22003	DIRECT	AH-64D 13210	1
2	6.56	06 22010	DIRECT	AH-64D 13211	1
2	6.59	ACRV 22020	DIRECT	AH-64D 13215	1
2	6.60	06 22015	DIRECT	AH-64D 13206	1
2	6.63	06 22005	DIRECT	AH-64D 13219	1
2	6.64	ACRV 22022	DIRECT	AH-64D 13209	1
2	6.67	ACRV 22028	DIRECT	AH-64D 13208	1
2	6.73	06 22013	DIRECT	AH-64D 13220	1
2	10.62	SA-14 18700	DIRECT	OH-58D 13176	1
2	10.65	SA-8 21781	DIRECT	AH-64D 13212	1
2	10.66	S-60 21820	DIRECT	AH-64D 13211	1
2	10.76	S-60 21816	DIRECT	AH-64D 13213	1
2	10.80	S-60 21805	DIRECT	AH-64D 13210	1
2	10.88	URAL-375 218	DIRECT	AH-64D 13212	1
2	10.90	URAL-375 218	DIRECT	AH-64D 13211	1
2	10.96	SA-8 21800	DIRECT	AH-64D 13213	1
2	11.04	S-60 21803	DIRECT	AH-64D 13210	1
2	11.17	S-60 21810	DIRECT	AH-64D 13213	1
2	11.19	URAL-375 218	DIRECT	AH-64D 13212	1
2	11.19	URAL-375 218	DIRECT	AH-64D 13208	1
2	11.22	URAL-375 218	DIRECT	AH-64D 13211	1
2	11.22	S-60 21832	DIRECT	AH-64D 13210	1
2	11.32	S-60 21819	DIRECT	AH-64D 13213	1
2	11.37	URAL-375 218	DIRECT	AH-64D 13221	1
2	11.39	URAL-375 218	DIRECT	OH-58D 13174	1
2	11.41	SA-8 21783	DIRECT	AH-64D 13207	1

Figure 7. "All Kills" Summary Report: Detailed report of shooter-target pairs sorted by time and type of kill

Systems Kill Report			
Kills By System Type			
Side	Target	Type of Kill	Total Killed
1	OH-58	DIRECT	3
1	OH-58D	DIRECT	6
1	AH-64D	DIRECT	3
1	M109A6	DIRECT	32
1	Q36	DIRECT	3
1	M1A1	DIRECT	76
1	M270	DIRECT	48
1	M198	DIRECT	13
1	120MM MTR	DIRECT	9
1	155MM SP	DIRECT	6
2	ACRV	DIRECT	66
2	G6	DIRECT	18

Dismiss

Figure 8. "System Kills Report": Summary report of total quantities of systems killed

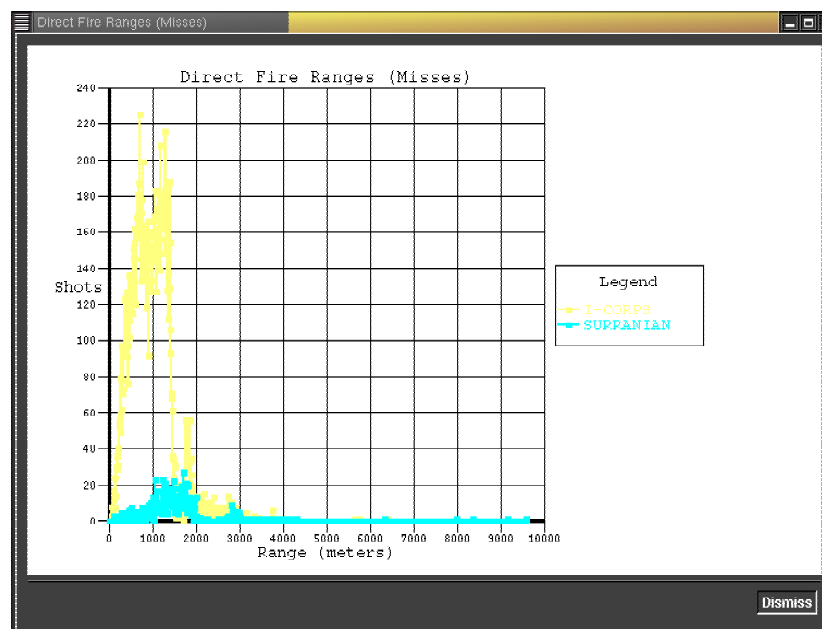


Figure 9. "Direct Fire Ranges (Missed)": Graphical summary of shots that were fired and missed their designated targets

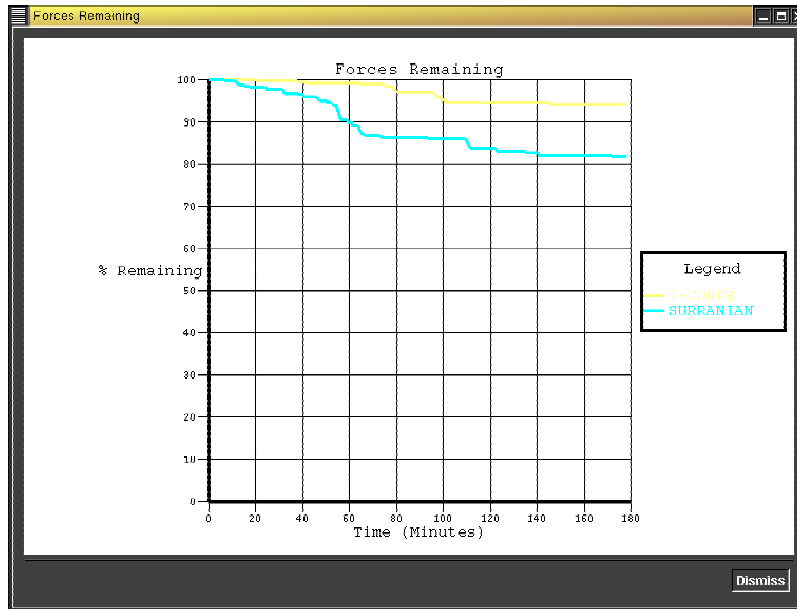


Figure 10. "Forces Remaining": Graphical representation of "friendly" and "enemy" forces levels based on the percent remaining over time

A major strength of the JCATS model is in its database tool, Vista. The Vista interface provides the user the ability to enter numerous levels of data that describes its interaction with other entities in the scenario. Figure 11 below shows one menu of Vista's graphical user interface (GUI) as an example of the amount of detail the user can incorporate into the scenario's entities.

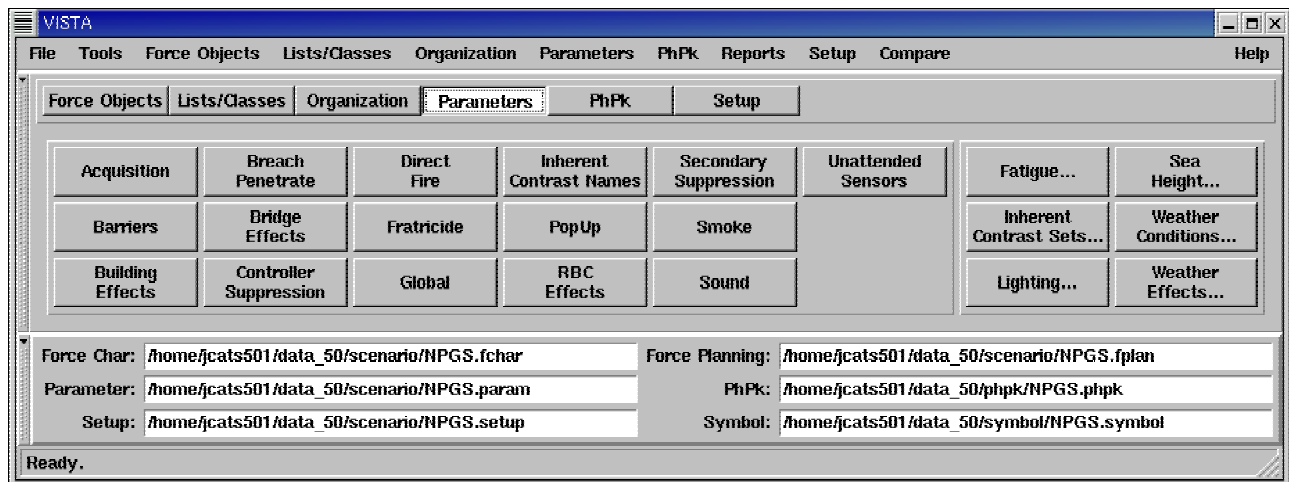
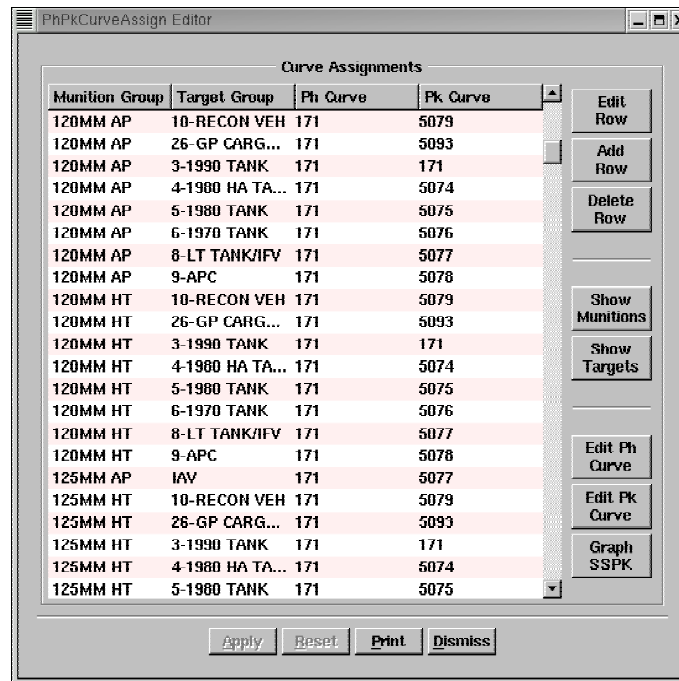


Figure 11. JCATS VISTA Editor

The user's ability to access the model's database through Vista provides the ability to model a scenario at any level of detail required. The details of the probability of hit (PH) and probability of kill (PK) can be adjusted to achieve a "good idea" of the outcome of a particular engagement or a precise modeling of a specific round of ammunition at a specific range against a specific target, see Figure 12.



The screenshot shows a software window titled "PhPkCurveAssign Editor". Inside, there is a table titled "Curve Assignments" with four columns: "Munition Group", "Target Group", "Ph Curve", and "Pk Curve". The table contains 24 rows of data. To the right of the table are buttons for "Edit Row", "Add Row", "Delete Row", "Show Munitions", "Show Targets", "Edit Ph Curve", "Edit Pk Curve", and "Graph SSPK". At the bottom of the window are buttons for "Apply", "Reset", "Print", and "Dismiss".

Munition Group	Target Group	Ph Curve	Pk Curve
120MM AP	10-RECON VEH	171	5079
120MM AP	26-GP CARG...	171	5093
120MM AP	3-1990 TANK	171	171
120MM AP	4-1980 HA TA...	171	5074
120MM AP	5-1980 TANK	171	5075
120MM AP	6-1970 TANK	171	5076
120MM AP	8-LT TANK/IFV	171	5077
120MM AP	9-APC	171	5078
120MM HT	10-RECON VEH	171	5079
120MM HT	26-GP CARG...	171	5093
120MM HT	3-1990 TANK	171	171
120MM HT	4-1980 HA TA...	171	5074
120MM HT	5-1980 TANK	171	5075
120MM HT	6-1970 TANK	171	5076
120MM HT	8-LT TANK/IFV	171	5077
120MM HT	9-APC	171	5078
125MM AP	IAV	171	5077
125MM HT	10-RECON VEH	171	5079
125MM HT	26-GP CARG...	171	5093
125MM HT	3-1990 TANK	171	171
125MM HT	4-1980 HA TA...	171	5074
125MM HT	5-1980 TANK	171	5075

Figure 12. PhPk Curve Assignment Editor: Links the munition and its target with a Ph and Pk curve

JCATS bridges the gap between the training and analytical modeling communities with tools that accommodate both aspects of modeling and simulation. This tool was chosen for this thesis based on its ability to remain a constant variable in the generation of results from both a "human-in-the-loop" wargame and "closed loop" analytical runs of the scenario.

D. MODELING THE AJCN IN JCATS

The modeling of the AJCN in JCATS took on two different aspects, one for a "human in the loop" experiment and one for "closed loop runs". The two different levels of incorporating human involvement allow for both subjective and analytical evaluation of the system with respect to its employment. The human in

the loop run provides insight into possible issues involved with the human aspect of employing a system based on previous experience and mindsets. The "closed loop runs" allows for several variations to be "played out" in a scenario to provide insight on the possible methods of employing the system. The modeling of the AJCN system is inherently singular to the two modes described above. Both methods are described in detail below with respect to how the AJCN was modeled. The insights gained from the two methods are discussed in the Simulation Results and Analysis portion of this thesis.

1. Human in the Loop (Wargame)

The modeling of the AJCN in JCATS for the "human in the loop" run was based upon the physical set up of the wargaming lab in which the experiment was conducted and the parameters in JCATS required to provide the user with the "intelligence" provided by the AJCN's capabilities.

a. Waveform Bridging

The wargaming lab provided the physical capability of the players to interact in such a manner as to model the waveform bridging capabilities of the AJCN. Those individuals that were under the AJCN's blanket of coverage could speak to one another and inform each other of enemy contact. The inherent ability to communicate "up the chain of command" was also enabled through the acting commander being able to oversee the operation from his perspective at the map, which was updated with intelligence from the various workstations. Thus, the waveform bridging capability modeling in JCATS was not required.

b. SIGINT

The AJCN nodes were modeled as "regular" UAVs with respect to the sensors mounted on a UAV allowing for LOS contacts to be made at an appropriate range for both air and land-based enemy systems. During the course of a JCATS run, the personnel at a particular workstation only see the "friendly" units set up on that workstation. The only time an enemy (or other friendly unit not controlled by that workstation) unit will appear on the screen is if one of the systems on the workstation has a LOS to that unit and the sensors inherent to the friendly system can range the enemy system.

The AJCN's SIGINT capability was modeled by this display of units on the respective workstations, representing the generation of enemy (and friendly) situational awareness based on the AJCN's extensive range capabilities. Upon gaining "contact" with the enemy units, the information was "transmitted" to other units in the area either through the chain of command via the waveform capabilities of the AJCN modeled as previously mentioned.

c. *Jamming*

Jamming was not incorporated into the Human in the Loop run.

2. JCATS - Closed Loop Runs

The modeling of the AJCN in JCATS during "closed loop runs" required the gross representation of the AJCN's most combat effectiveness enhancing capabilities. Given the capabilities and limitations of the JCATS model, modeling the AJCN included the capabilities of SIGINT, jamming, and waveform bridging. The methods used to model the AJCN stemmed from the need for the system to incur a quantifiable difference in the outcome of a battle, namely the relative amount of attrition to the enemy and friendly forces. The actual methods of modeling these capabilities and their mapping back to the actual AJCN capabilities are fully explained in the following paragraphs.

a. *Waveform Bridging and SIGINT*

Waveform bridging and SIGINT were combined since they primarily serve to enhance the situational awareness of the units that receive information updates from the AJCN in theater. Since JCATS does not yet incorporate autonomous agent behavior or model communication between entities, the appropriate responses of units to "enhanced situational awareness" were restricted to those cause-effect relationships inherent to the JCATS model. The most applicable relationship that would result in measurable effects on the "virtual battlefield" was the Forward Observer to Direct Support element relationship.

The AJCN "nodes" were given range of coverage based on the capability parameters of the supporting platform. The AJCN were set up to provide Forward Observer support. In JCATS, an entity that is Forward Observer

capable will provide Calls For Fire to any indirect munitions system in its same unit that is set up to provide Direct Support (DS) for indirect fires. The AJCNs' ability to act as a Forward Observer in JCATS maps to the AJCN's real capabilities in the following manner:

1. SIGINT provides units enemy unit location information that can be used for targeting by indirect fire systems.
2. Waveform bridging allows all units, regardless of communication system, the ability to obtain the intelligence updates of enemy location and activity.

The sequence of events in JCATS occurred in the following manner:

1. The AJCN moves along its designated route.
2. The AJCN SIGINT "sensors" make contact with enemy units.
3. A Call For Fire is sent to all DS artillery units on the friendly side.
4. Those friendly artillery units within range of the enemy unit initiate their firing sequence.

The tangible result of modeling in this manner is the number of enemy units killed. Although the engagement of enemy units may not always be the result of information gained through SIGINT and the cross-talk between units enabled by waveform bridging; for a closed loop run, the number of enemy units killed provides a measure of effectiveness for the AJCN's capabilities.

During initial experimental runs, this method of modeling was successful. Artillery units that were within range and had applicable target pairings to the targeted enemy system deployed their munitions consistently.

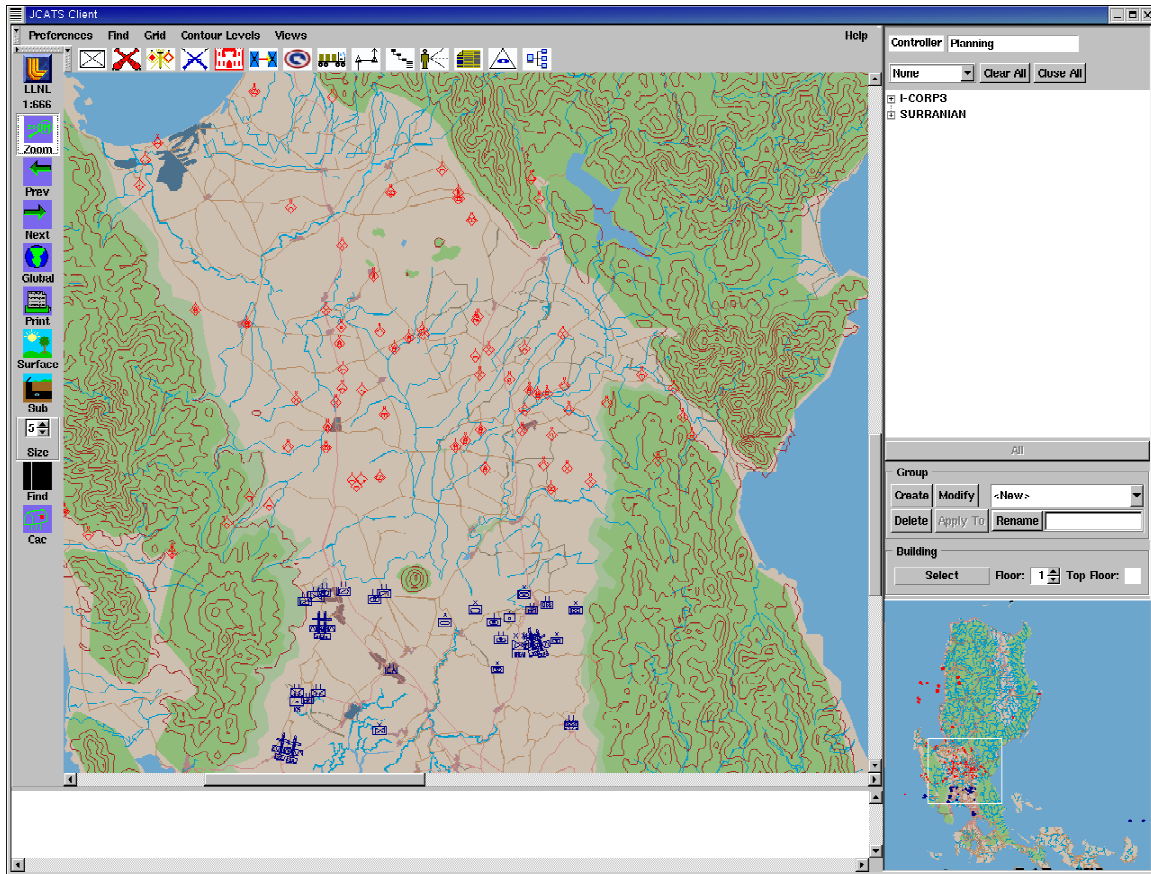


Figure 13. Initial Array of Forces for "Closed-Loop" Scenario

b. *Electronic Warfare (EW)*

The electronic warfare capability of the AJCN was also modeled using the FO capability provided by JCATS. The EW aspect of "jamming" enemy radio frequency was achieved through the analogy that when a platform's communication systems are "jammed" and not afforded the capability to communication with other friendly units, it is effectively "suppressed."

In JCATS, when an entity is suppressed by artillery it will stop until the artillery barrage has stopped. It will then continue on its prescribed route. This maps to the idea that a platform whose communications systems are being jammed loses its situational awareness and ability to effectively maneuver and fight with its parent unit. The platform will tend to stop and regroup to shift its

means of communicating with its parent unit to some analog means of communication or wait until the jamming ceases.

To achieve the suppressive "jamming", the AJCN entity was given a direct fire weapon with High Explosive (HE) munitions with a Probability of Hit = 100% and a Probability of Kill (PK) = 0% that could be "called for fire" by its FO. The PH/PK combination means that the AJCN's jamming "weapon system" will hit whatever it fires at, but will not cause any physical damage to the engaged system. In JCATS, the effect of a PK of 0% is suppression. The AJCN would "call itself for fire" and send a barrage of "jamming signals" at the enemy entity, thereby suppressing the enemy and stopping its movement. The AJCN was given a very large number of "munitions" so the jamming would continue until the enemy left the AJCN's cone of influence.

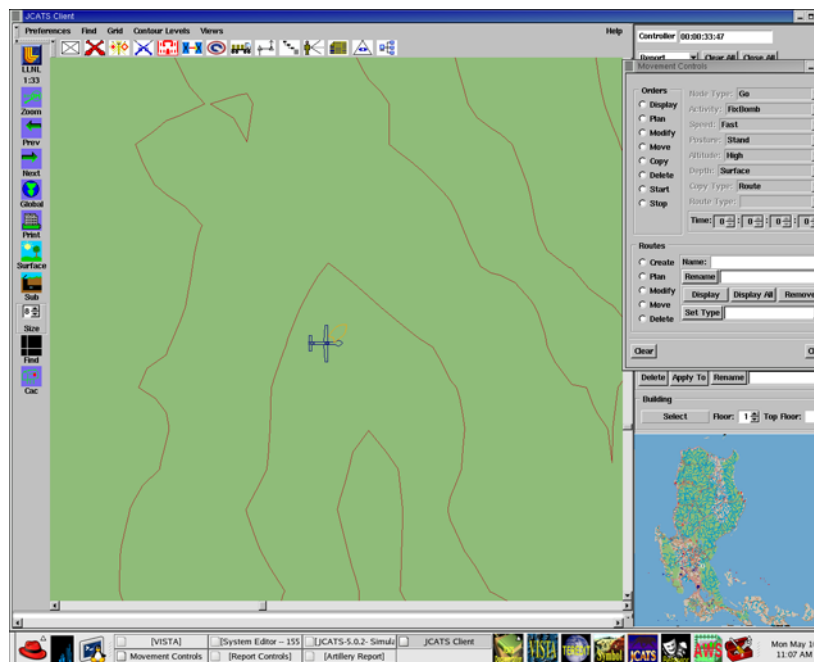


Figure 14. AJCN sending off a "jamming signal" to a targeted enemy system

During initial experimental runs this configuration was successful, with the caveat that the AJCN would "jam" only one enemy entity at a time. This occurred due to the JCATS algorithm for artillery pieces that dictates that once a fire mission is called, it will continue until either the target is destroyed or the firing unit has expended all its ammunition. Once the AJCN's flight path moved

its cone of influence out of range of the particular enemy entity it was "jamming", it would shift to "jamming" a new enemy entity.

3. One-Tier versus Three-Tier

Due to the organizational set up of JCATS, only one tier was evaluated during the experimental executions. This impeded our ability to comment on the self-healing network aspect of having three different tiers of AJCN operation within a theater of operations. However, once the bottom-tier is evaluated on its effect on the battle scenario outcome, the number of middle- and top-tier AJCN can be extrapolated to generate a possible number and disposition of the various tier-levels of AJCN.

4. Experimental JCATS Executions

The runs were to be executed in groups of 30 to accommodate statistical significance in the results and allow a comparative analysis of the results. The description of the runs follows:

BASELINE: No AJCN systems incorporated

AJCN_1-6: A series of six scenarios with between one and six AJCNs assigned to a Division-sized unit respectively.

5. Database Confound

During the course of experimenting with the AJCN's capabilities in JCATS, as previously mentioned, it was determined that the database that was made available did not have the detail required for the conduct of the analytical portion of this thesis. The lack of required detail involved many facets of the database: Ph/Pk values, target pairings, sensor characteristics, and others.

The scenario detailed in Chapter Three of this thesis was of a magnitude that required a large number of "friendly" and "enemy" systems, weapons, munitions, and sensors. The generation of an acceptable database for these elements and their interactions would require a significant amount of time (on the order of man years) and effort that was beyond the scope of this thesis and the time available. To our knowledge there was not another database available that addressed the issues mentioned above for the systems required for this analysis.

The following paragraphs give some of the problem areas we encountered and a brief overview of the process of generating a system in JCATS. A "system" is comprised of four main components: a platform, a weapon, a munition, and a sensor. A platform may have multiple weapons mounted on it (i.e. an M1A2 may have both the 120mm main gun and a .50 caliber machine gun), which can fire multiple munitions (i.e. 120mm HE, 120mm HP, etc), and may have multiple sensors available to the platform (i.e. binoculars, night vision sights, etc). Each component of the system must be detailed in the database, beginning with the munition.

The munition editor in JCATS requires that detailed data relating to the munition's capabilities be input. Information required includes: munition type, munition reliability, minimum and maximum range, velocity, time of flight at different ranges, suppression effects on targeted vehicles, and many others. This detail enhances the simulation's ability to effectively and precisely adjudicate the effects of the munition on a target. Below are some examples of input windows that are used when building a munition.

The screenshot shows a software window titled "Munition Editor -- 120MM HE". It features a tabbed interface with the following tabs: General, Conventional, Suppression, Ballistics, Range, HE, and DIS. The "General" tab is currently selected. Within this tab, the "Munition Type" is set to "HE". There is a "DODIC" field and a "Logistics Tracking" checkbox. Under "Fire Modes", there are four checkboxes: "Auto Direct" (unchecked), "Planned Indirect" (checked), "Planned Direct" (unchecked), and "Direct Support" (checked). The "Mission" is set to "ANTI TANK" and the "Crater Radius (m)" is set to "2". On the right side, under "Munition Reliability", there are three input fields: "Open(%)" with a value of 98, "Wood(%)" with a value of 98, and "City(%)" with a value of 98. At the bottom of the window are four buttons: "Apply", "Reset", "Print", and "Dismiss".

Figure 15. Munition Editor-General: User designates the munition type, fire modes, mission, and munition reliability

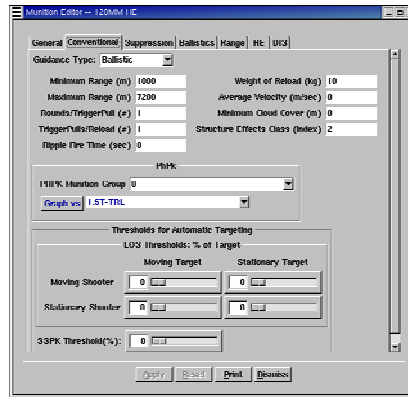


Figure 16. Muniton Editor-Conventional: User designates guidance type, ranges, and munition velocity

The critical step in developing munitions is the generation of Ph/Pk tables. These tables describe the effect of each munition against a particular target, commonly referred to as a "target pairing". The detail and relative accuracy of this data will determine the level of "realism" portrayed in the simulation. Particular attention must be given to all possible targets for each munition. If a target pairing does not exist for a particular munition and target, the platform carrying the munition will not engage the target even if it would in a "real world" situation. We learned that there were problems with most of the weapon systems' Ph/Pk tables. Correcting this would have taken considerable time to resolve and was beyond the scope of this thesis.

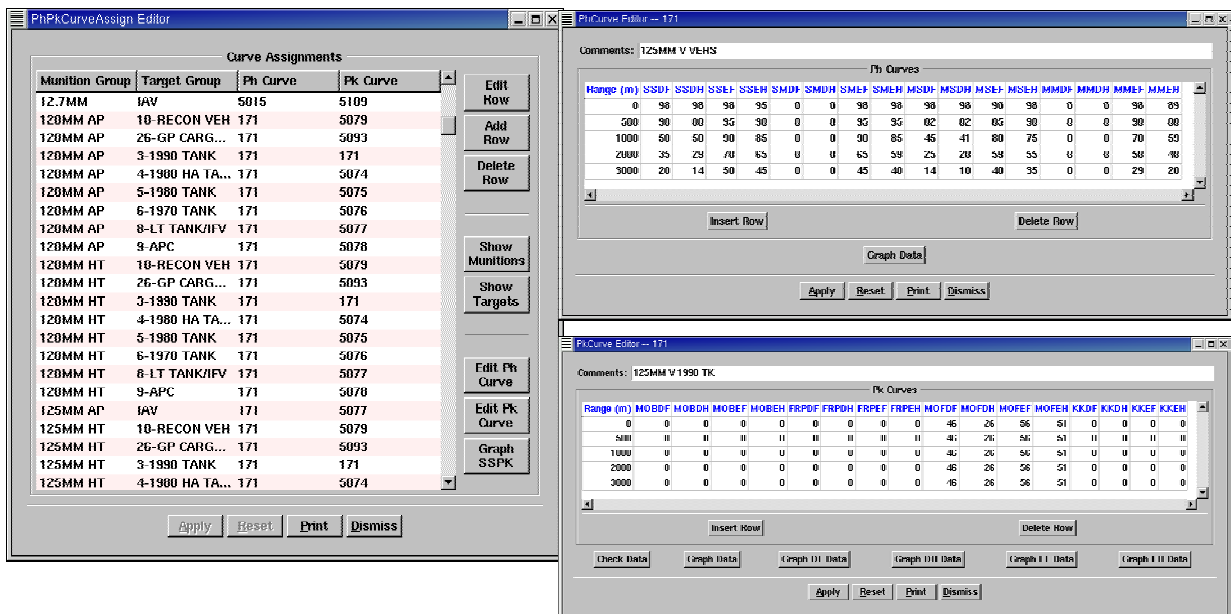


Figure 17. PhPk Curve Assignment Editor and Ph and Pk Table Examples

JCATS does provide a useful tool to check if all target pairings have been generated. The PhPk Curve Assignment Editor shows all the munitions and all the target groups and shows which are "paired". As stated before, those munitions not "paired" with a target group will not engage that target. Figure 18 shows the format PhPk Curve Assignment Editor. We discovered that target pairings in our scenario were incomplete, thus hindering our ability to simulate a battlefield with appropriate engagements between forces.

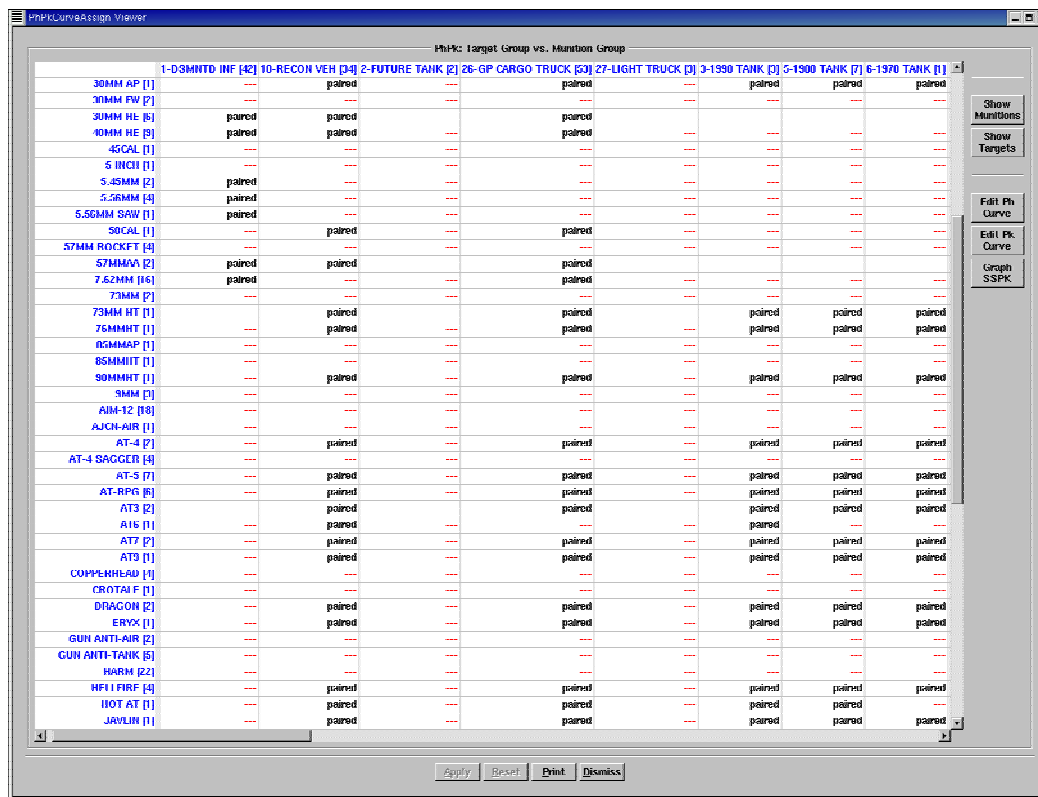


Figure 18. PhPk Curve Assignment Editor: Munitions not "paired" with a target will not engage that particular target, regardless of what might occur in the "real world"

The weapon editor requires the user to define several operational parameters related to the use of the weapon. These include setup time, lay time, minimum cycle time, reload time, and others. The figure below (Fig 19) shows the input window in the weapon editor.

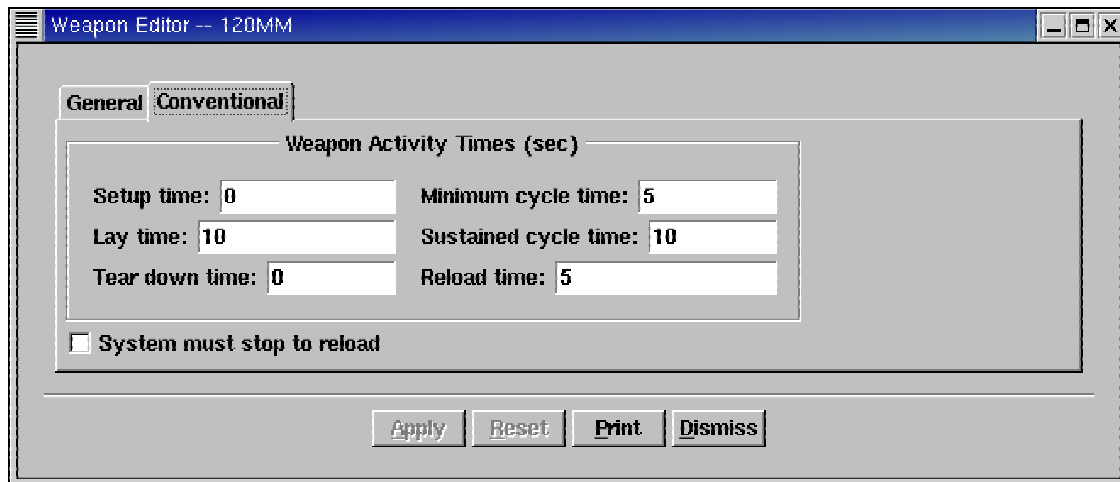


Figure 19. Weapon Editor: Requires the user to define several operational parameters of the weapon

Sensors can range from the human eye to an air-to-air radar (see Figure 20). The sensor editor requires the user to designate several parameters that define the capabilities of the sensor (see Figure 21).

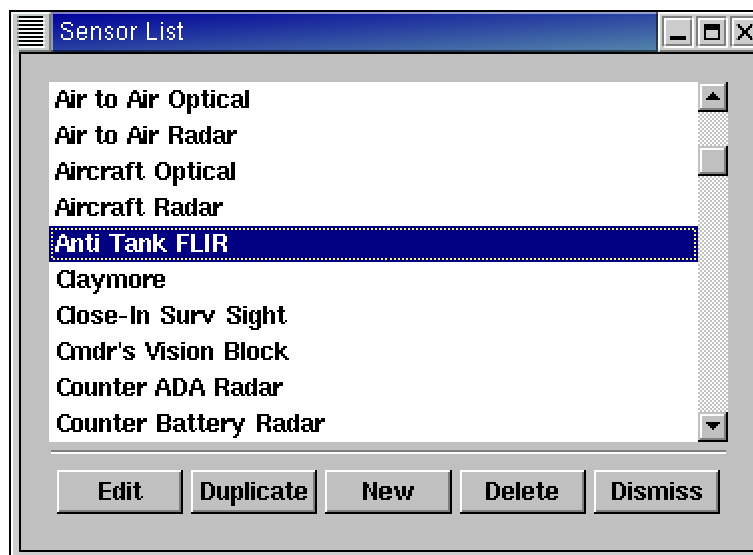


Figure 20. Sensor Editor: List of sensors generated in the database

The 'Sensor Editor -- Anti Tank FLIR' window contains the following fields and controls:

- General** tab is selected.
- Sensor Type:** ACQUIRE Thermal (dropdown menu)
- Minimum Range (m):** 0
- Maximum Range (m):** 10000
- Horizontal Field of View (degrees):** 6.8
- Acquisition scan interval (sec):** 2
- Acquisition scans per LOS check (#):** 5
- Max Concurrent Acquisitions(#):** 20
- Is Electronic:** ☒
- Reliability (%):** 100 (with a slider bar)
- Buttons at the bottom: **Apply**, **Reset**, **Print**, **Dismiss**

Figure 21. Sensor Editor-Data input window requiring user to define several parameters describing the functionality of the sensor

The system editor is the final step in generating a platform. This editor brings all the previously mentioned pieces together on a platform that is generated within the context of several menued windows. Figure 19 shows the "Stations" window that describes the platform's weapon and the munitions, by quantity, that the weapon will have available. A sensor is also associated with the specific weapon. As can be seen from Figure 22, the platform may have more than one station, which corresponds to a platform having more than one weapon system, each with their munitions and sensors.

The 'System Editor -- M1A2' window features a sidebar with menued options and a main configuration area:

- Sidebar (left):** General, Mount, Vulnerability, AutoDirect, Detectability, Defilade, Stations, Casualty, Transfer, Launch, AVLB, Vehicle, Dimensions, Pass/Crew, Carry, Ground, Slope.
- Main Area:**
 - Tabs: Station 1, Station 2, Station 3 (Station 1 is active).
 - Sensor:** Thml Sight (dropdown menu)
 - Weapon with Munitions:**

Munition Rounds	
120MM	75
COAX	45
120MM AP	
120MM HT	
 - Buttons: **Insert Row**, **Delete Row**
 - Checkboxes: ☐ FO Capable, ☐ LD Capable
 - Buttons at the bottom: **Apply**, **Reset**, **Print**, **Dismiss**

Figure 22. System Editor: User defines the platform's characteristics, platform's weapons with their associated munitions and sensors

The difficulties in modeling the AJCN in JCATS are beyond the systems inadequacies in modeling C4I systems. As previously stated, the programming of all entities and their attributes within the database is a very time consuming and labor intensive task. Most database construction consumes a full staff for at least 6 months before completion. [Ref. 31]

Due to the time required to build a suitable database we found it necessary to acquire an already constructed scenario in order to expedite our analysis. After searching for a representative scenario and database, we finally found one that we could use and began detailing it to meet our needs. Once we began modeling our scenario we noticed some peculiarities in our results. Many of the systems within the JCATS were not engaging other systems at expected ranges nor were they displaying the proper effects. The errors were determined to be database inadequacies. Specifically, many of the probability of hit and probability of kill tables along with the pairing of systems were not well-constructed or did not exist. We determined that we did not have the time to fix these errors so we decided to find another software system to handle the simulation portion of this thesis. Over the period of three weeks we reviewed several other simulation packages and found that the data base construction would be the obstacle to get past for all of them but one, Point of Attack 2 (POA 2).

POA 2 had only been built for the military community as a research project. It had been developed as a weapons simulation tool for the Air Force, but had not been used for any other simulations up to this point. It had a database within the program that was very extensive and accurate. It modeled numerous real world systems and allowed for easy creation of new systems, to include C4I systems. Having only 3 months left to complete our work, it appeared that this new simulation package could model our scenario with enough accuracy to provide insight into the development of the CONOPS for the AJCN.

Figure 23 shows a graph of the Ph data found in our JCATS database for a 40mm High Explosive round. When compared with the POA 2 data for the

same ammunition in Figure 24, we see a level of detail and accuracy in the POA 2 database that was not found in the JCATS database that we had available. After a thorough examination of the POA2 database as compared to the JCATS database, we decided to use POA2 for the closed loop simulation analysis of the AJCN.

In the figures below we will look at one example of the differences found between the two models' databases. We will look at a 40mm High Explosive round which is fired from a MK19 40mm Machine Gun. For the purposes of this comparison we took used unclassified weapon and munition data available from the Military Analysis Network web site. The 40mm has a maximum range of 2200 meters and a maximum effective range of 1600 meters. [Ref. 32] We now compare this data against the data represented by the JCATS and POA 2 Ph curves in Figures 23 and 24 respectively.

The JCATS Ph curve, Figure 23, for the 40mm munition has several Ph values that account for ranges up to 2800 meters, well beyond even the maximum range of the munition. The dramatic drop in Ph to below .50 between 0 to 500 meters is a significant misrepresentation of the munition given that its maximum effective range is 1600 meters. Although we were not able to access the Ph data for the 40mm munition, it would be reasonable to assume that the maximum effective range should generate at least a .50 Ph against a target. It should be reiterated that this discrepancy with the munition Ph values does not reflect poorly on the JCATS model itself, only the database we had available.

The POA 2 ammunition properties screen, Figure 23, for a 40mm High Explosive round shows quite a different view of the munition's capabilities. The "Accuracy vs. Range" portion of Figure 23 represents the varying Ph for the munition between 0 and 1800 meters. This range span correlates well with the maximum effective range of 1600 meters. After comparing many Ph/Pk tables and graphs between the two databases, we determined that the database made available with the POA 2 model met the needs for our analysis.

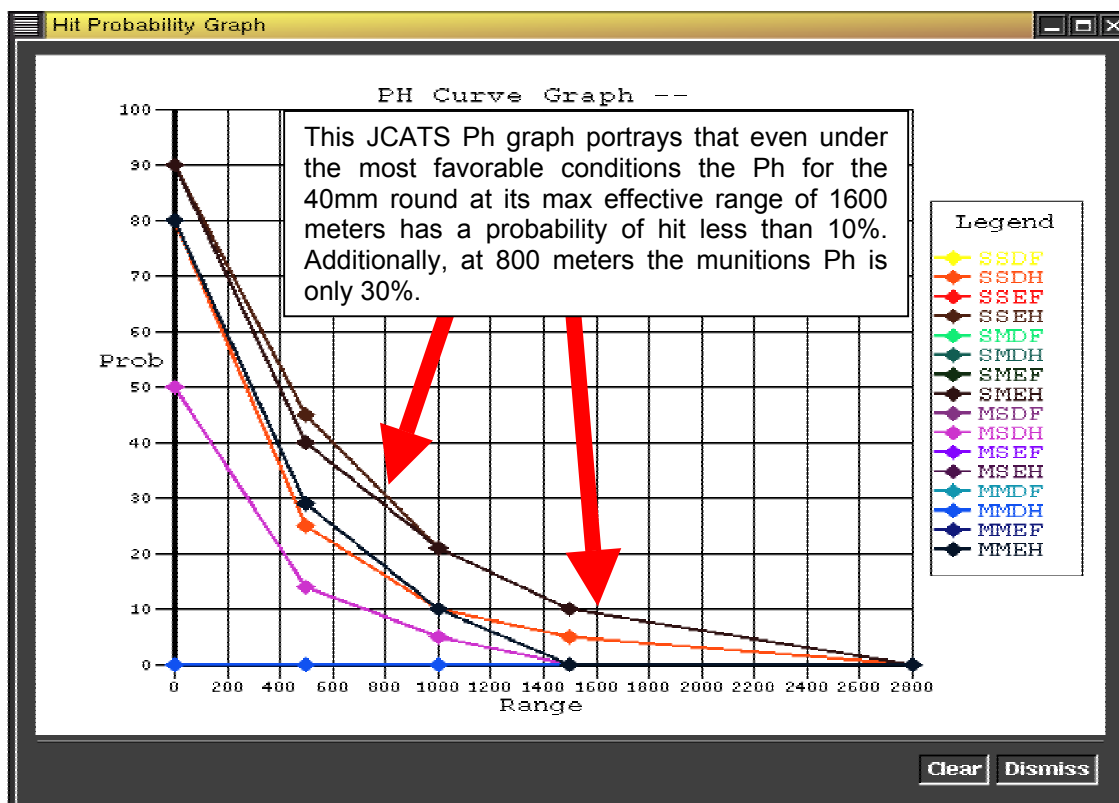


Figure 23. JCATS Ph Curve Data for 40mm Munition

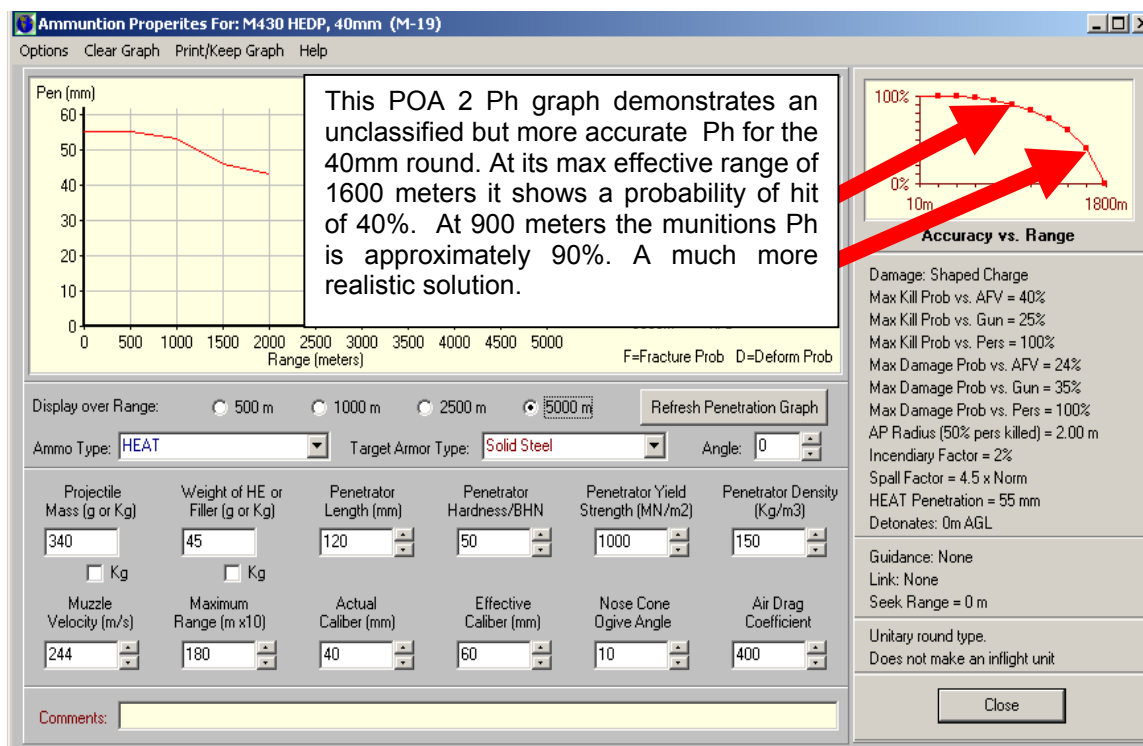


Figure 24. POA2 Ammunition Properties for 40mm Munition

It should be noted that the Joint Forces Command (JFCOM) is currently spearheading a "JCATS Standard Database Initiative" which will alleviate many of the issues that surfaced during the conduct of this thesis. The initiative will create an unclassified database comprised of vehicle, weapon, and munition parametric data that "would be used as a base line for simulation events." [Ref. 21] The military systems portion of the standard database is currently slated for completion June 2005.

E. POA 2 MODEL

The Point of Attack 2 (POA 2) software wargaming package is a physics-based conflict simulation model produced by HPS simulations in partnership with the Air Force Office of Scientific Research (AFSOR). The intent for POA 2 was to develop a weapon system evaluation tool for acquisition and modification of new or current weapon systems. [Ref. 25]

POA 2 provides an interactive, high resolution, entity-level, conflict simulation that models two sided ground combat with limited air/naval operations on a user defined hexagonal or square digital terrain map. POA 2 models both aggregate and individual systems. It provides users with the capability to detail the replication of small group and individual activities all the way up to theater level operations.

Features include:

- ☐ Highly detailed and comprehensive
- ☐ Tactically oriented
- ☐ Extremely flexible
- ☐ User customizable
- ☐ Zero(computer vs computer), one or two operators
- ☐ Uses and Applications include:
 - ☐ Training and Exercises
 - ☐ Analysis and experimentation
 - ☐ Mission Planning and Rehearsals
 - ☐ Wargaming

POA 2 can simulate hundreds of individual elements. It can operate on a windows-based workstation or a laptop computer. It typically simulates battle between two opposing sides (often called red and blue forces), but accommodates neutral relationships such as those of civilians. Depending on the parameters established for the conflict, an entity's posture and actions can be varied as the operator desires. Simulation operators see the actions of both forces and are able to view whatever intelligence is acquired about opposing forces via a windowed output screen called the Combat Phase Report, see Figure 25.

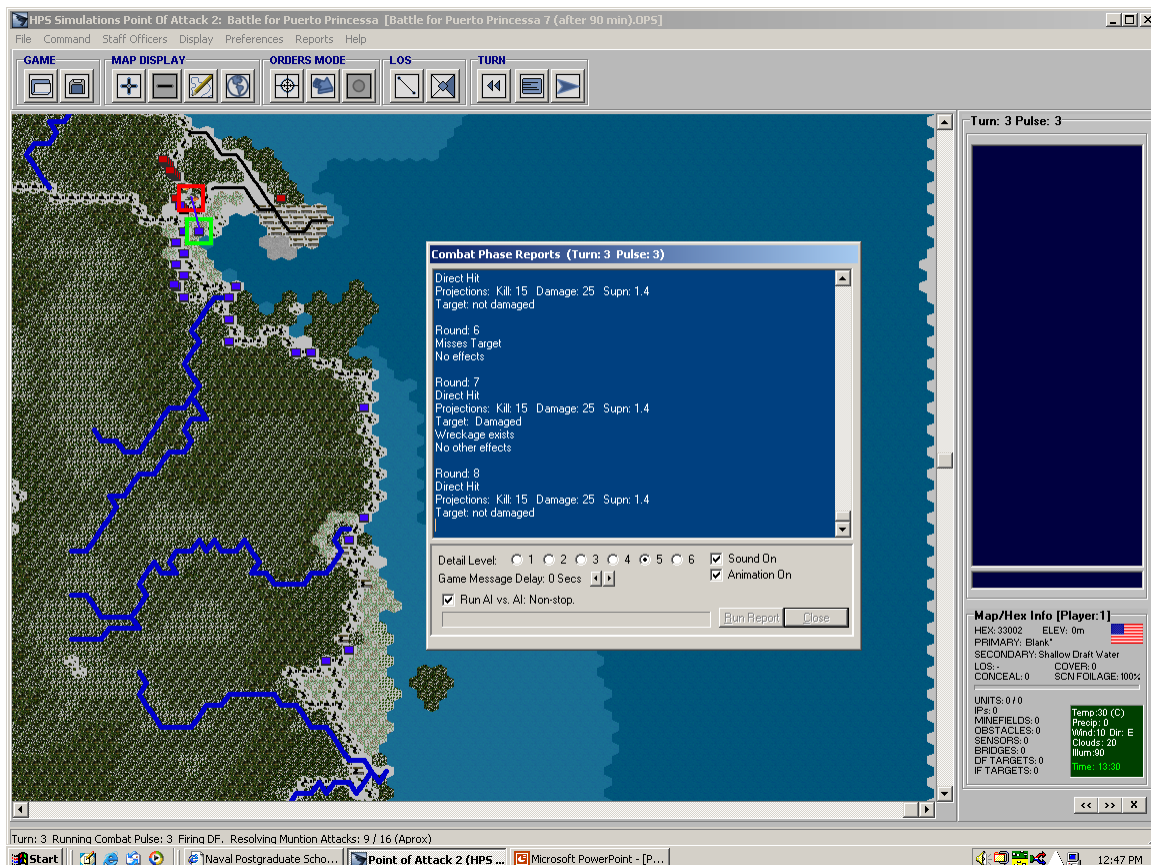


Figure 25. Combat Phase Report

POA 2 is executed as a turn-based simulation. It is not dynamic. Each operator defines its unit parameters and goals and then, after the simulation is initiated, the operators take turns and adjust their forces as the simulation

continues. In a computer versus computer simulation (known as AI versus AI, AI for Artificial Intelligence), the simulation uses the information acquired in each turn to make plans or orders for following turns. For the purposes of our experiment both sides use AI. Some parameters for the AI, such as morale, have adjustability during the set up of a scenario. The adjustment of parameters such as morale all affect how the entities react with each other during the course of a simulation. In AI mode no two game results will be exactly the same, although the results will generally follow the same pattern. For example, a single scenario run 2 different times will usually produce similar outcomes but the force exchange ratios will be different. The AI requires an initial value also known as a “seed” to begin its execution. POA 2 uses a pseudo random number generator algorithm to determine this seed value. Although this type of random number generator is considered to not be truly random, such as rolling a dice, it is broadly used in simulations and proved to produce consistent results for our application. [Ref. 26]

The duration of games may vary from a few minutes for a brief exercise to hours for a complex simulation involving many units and entities. Selected shorter scenarios may be run several times so that statistical analysis can be used to evaluate a particular tactic or weapon system as in this thesis.

Time required to set up a POA 2 exercise varies depending on the number and kinds of combat forces and, especially, the kinds of topography to be modeled. Terrain can be modeled with extraordinary fidelity. Rivers, for example, can be characterized by their current, depth, and underwater obstacles. Terrain data can be entered or imported, including correct elevation and geographical features, from another terrain editing software program titled ADC 2 (Aide de Camp 2). [Ref. 27]

The detail of the terrain significantly affects movement of troops, aircraft, tanks, and maritime operations in POA 2. For example, a helicopter cannot safely land in a wooded environment, an amphibious landing craft must negotiate unsatisfactory shorelines, vehicles move slowly through swamps, and soldiers

slow considerably when marching uphill. Environmental factors also affect mobility. Such examples are adverse weather, nightfall, and smoke, etc. [Ref. 27 & 28]

Generally, the simulation area for the terrain coverage is dictated by the number of hexes or squares per a known unit of measure (i.e. kilometers, meters, etc.). For this thesis the unit of measure referenced is kilometers. This overall area is known as the playbox. The playbox can be made as large as 63,000 hexes, but the cost for this is degradation in fidelity. Increasing the playbox size is done by decreasing the number of hexes or squares per unit of measure. For the size of our simulation the hexes covered an area of 1 square kilometer. At any scale an operator can zoom in to view details such as individual entities, roads, rivers, buildings, etc. [Ref. 28] Operators have at their disposal a vast range of weapons, including tracked and wheeled vehicles, aircraft, ships, and even systems that are in the development or conceptual stage such as the one studied in this thesis. Individual soldiers may have machine guns, rifles, antitank weapons, mortars, and other munitions. POA 2 models these systems in great detail. These details and parameters can be viewed and edited in the Data View section of the POA 2 package. The Data View window, see Figure 26, allows users to create, modify, and edit all system to include C4I systems and directed energy weapons.

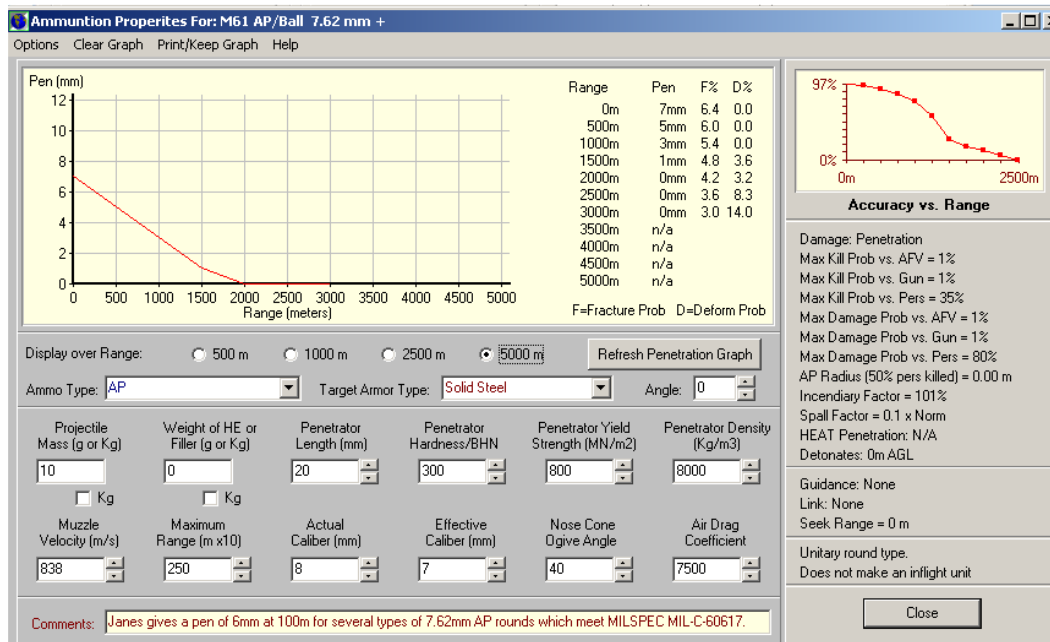


Figure 26. Data View for Ammunition Properties for Armor Piercing 7.62mm ball

Our map was constructed over the course of two weeks. Within this time the several layers of information were overlayed onto the "map surface" to achieve the final product. The first layer was the background picture of the island of Palawan. Although this picture is not necessary for the conduct of the game, it provided us with a reference upon which to build the following layers. The picture itself was created from a map that was cropped into 12 pieces to accommodate the file size restrictions of ADC 2, and then reconfigured in the ADC 2 map editor. Elevation data is then input for each hex on the map. Elevations ranged from 0 feet at sea level to mountain ranges at 6900 feet. The next layer is terrain data. The terrain data was chosen based on paper maps of Palawan. Each of our map's 62,013 hexes was designated both an elevation and a terrain property.

Many military operations can be modeled in POA 2. Its strengths are its force-on-force engagements, but it is also is able to provide numerous other features to the military community, such as:

1. Allows for interactions with non-combatants, such as refugees and civilian vehicles.
2. Reduce the cost and time of weapons systems development and modification.
3. Allow a wide range of input from different agencies and personnel.

POA 2 has the ability to aggregate entities (soldiers, tanks, or other individual units) into a group such as squads, platoons, battalions, or a unique size force and then view and control that force as one icon. This allows large formations to be easily viewed and controlled while the program tracks and records activity at the individual entity level. When required, an operator can select a unit, right click, and examine its status.

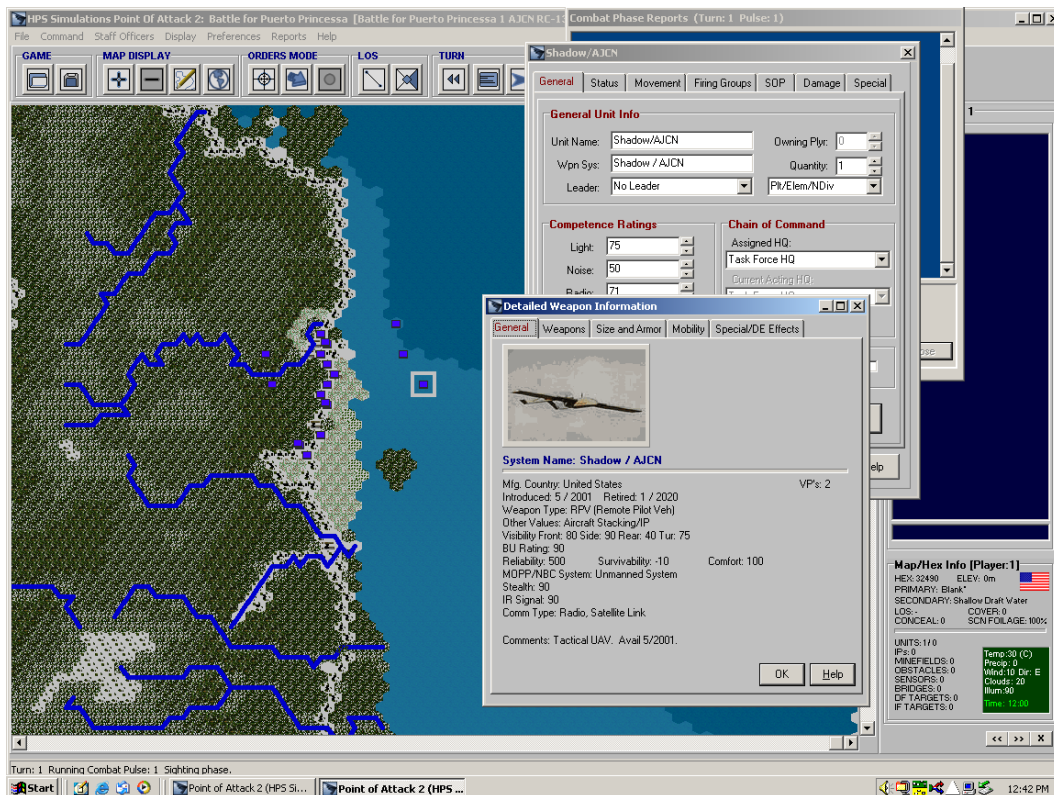


Figure 27. Unit Information Details

Weapons effectiveness in POA 2 is determined by probability-of-hit and probability-of-kill statistics based on published statistics by DoD and other reliable sources, such as Jane's. Using this and environmental data, POA 2 calculates and determines the outcomes of engagements between opposing forces. Not all engagements are kills. POA 2 uses all aspects of engagements to determine if a combatant was immobilized, killed, or a miss.

Human entities begin with a certain amount of morale in POA 2. Their morale level can fluctuate based on the activities of that entity and its initial conditions. For example, a soldier's morale decreases when he is performing more difficult tasks, such as fighting for extended periods of time. Health and training of soldiers can also play a part in POA 2. These parameters are set by the operators and are degraded or increased according to conditions.

Battle outcomes are computed using a weighted value system. Values are assigned to systems based on their relative combat power. For example, an infantryman may be assigned a value of one and a tank a value of 50. When an engagement occurs, the weight values of the systems involved in the engagement are taken into account to adjudicate the outcome. The weighting scheme is consistent through all the forces represented in a particular scenario.

Simulation operators can analyze the results of the executed simulation in the Game Results display window. This is displayed at the end of a wargame and allows the user to gain insight on the outcome of the battle. For the purpose of this thesis, the software development team at HPS simulations created very specific MOE Reports that not only measure common battlefield statistics but add additional information dealing with communications between entities on the battlefield.

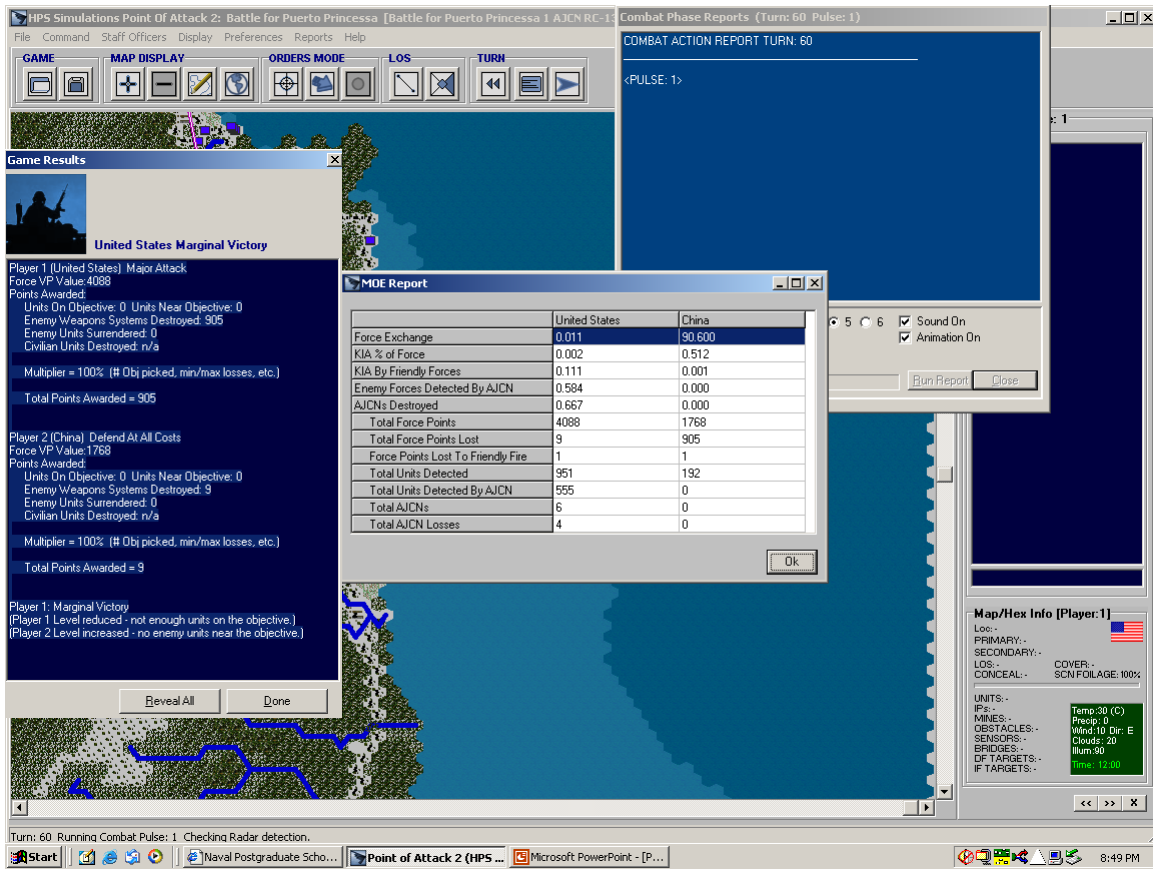


Figure 28. Game Results and MOE Report

One of POA 2's advantages is its applicability to all the military services and government agencies. Although each service has its own weapons, methods of combat operations, and specialized simulation programs and perceived threats, POA 2's versatility allows it to be a powerful resource for all of them. Because it has the ability to model all of the services' forces and most threats, as well as those of other security organizations, it also encourages better coordination among agencies, both in planning missions and in training personnel.

F. MODELING THE AJCN IN POA2

Modeling of the AJCN in POA 2 required a representation of the 3 major system capabilities that the AJCN brings to the battlefield: SIGINT, waveform

bridging, and jamming. Through its use of autonomous interactions POA 2 provided simulated representations for each of these capabilities. In the following paragraphs we will step through the implementation of each of these attributes to build an AJCN system in POA2.

The AJCN was mounted on 2 UAV systems and a KC 135 aircraft platform which already existed in the POA 2 software package. The UAVs were the Shadow and the Global Hawk. The manipulation of these aircraft to provide the necessary capabilities for the AJCN is done in the Data View window of the POA 2 simulation package. The Data View interface provides the ability to modify existing platforms and add or delete capabilities as needed. For the AJCN system most of the data was represented in the “Communications/Jamming System Data table” of the Data View. The Communications/Jamming System Data table contains special systems that can enhance friendly communications and degrade that of the enemy. These systems can also function as detectors.



Figure 29. Communications and Jamming Systems Table

Communications/Jamming systems in this table are assigned to Weapons systems (aircraft, ships, vehicles, troops, etc.) in the Weapons System Data Editor. The commo/jamming system parameter fields used for the AJCN are as follows:

100% Effectiveness Range

The maximum range, in meters, at which the system will use full effectiveness values.

50% Effectiveness Range

The range, in meters, at which the system will operate at 50% effectiveness.

Unit Levels Affected

Designates the unit level (i.e. Battalion, Brigade, etc.) that a system will influence.

Transmission Time Factor

This field determines the rate of increase or decrease in transmission duration between entities or between an entity and his higher headquarters. The change is entered in relation to the 100% effectiveness range. For example, if the time increases by a factor of two, 200% would be entered to relate a doubling of the time it would take to execute a transmission. Values less than 100% relate an increase in the speed of a transmission and 100% relates no effect on transmission time.

Transmission Types Affected

Designates the types of transmissions the system will affect, data and/or voice.

Transmission Configuration

The configuration describes the situation of the sender to the receiver, based on their position relative to the ground surface. Units at elevations of 10 meters or less AGL (above ground level), are considered on the surface. This value determines which types of transmissions are affected.

Detection Probability

The known probability that the system will detect enemy systems.

Detection Type

Designates who will be detected by the system; friendly or enemy units.

Effectiveness Adjustments

Any of the following situations that will reduce the system's effectiveness:

Enemy EW: Expressed as a known percentage

Enemy Com Level: The enemy force's communications level (as determined by the average command delay) will reduce the effectiveness of jamming and detection of enemy units. The loss will range between 1% for command delay values of less than 300 seconds, and complete (100%) loss for forces with zero second command delays. The reduction is determined hyperbolically, so that a command delay of 60 seconds only causes a 25% reduction.

Enemy Communication Discipline: If the sending unit is an enemy, its communications discipline rating reduces detection effectiveness by 1/2% for each rating point. It does not affect jamming (time adjustment).

Enemy EW unit in range: If there is an enemy EW unit within range, the enemy force's EW rating will be doubled, and then will proportionally decrease effectiveness in all areas. For example, a rating of 25 will make the system 50% less effective.

LOS Required: If the situation warrants, the system must have an LOS to the sending and/or receiving unit that does not hit the ground.

For speeding up friendly transmission, the system must have an LOS to both the sender and receiver.

For jamming enemy communications, the system must have an LOS to the receiver.

For detecting friendly or enemy units, the system must have an LOS to the sender.

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VI. ANALYSIS

This analysis portion of the thesis applies only to the closed-loop constructive simulation runs that were completed using POA2 for the purpose of gathering analytical results to complement the insights gained through the wargaming process. The results will be presented primarily in table and graph format to provide the reader with an understanding of the simulation output. Insights that can be gleaned from the output will be presented following an appropriate presentation of the data.

A summary table below, Figure 30, shows the mean values for the data generated from each of the six scenarios. A brief explanation of the data represented in the table follows.

		Baseline	1-KC135	1-Shadow	1-KC135 + 1-Shadow	1-KC135 + 2-Shadow	1-KC135 + 5-Shadow
US	Begin Strength	4028.4	4078.4	4030.267	4080.4	4082.133333	4088.766667
	# US Killed	382.267	334.333	114.1	255.8333333	81.46666667	45.83333333
	USKilled/BeginStrength	0.09489	0.08198	0.028312	0.064239802	0.019956898	0.011209735
China	Begin Strength	1769.23	1769.6	1769.8	1769.033333	1768.6	1768.2
	#China_Killed	458.933	401.7	308.8	548.5	861.1333333	830.5333333
	ChinaKilled/BeginStrength	0.25938	0.22701	0.174496	0.303675214	0.486911788	0.469727023
	ForcePts lost to Friendly Fire	15.9333	15.9667	5.433333	9.4	1.3	1.733333333
Detected	# Detected by US + AJCN	662.3	698.8	1237.1	1342.733333	1412.766667	1668
	# Detected by US	662.3	698.8	785.5667	811.4	864.1	1075.266667
	# Detected by AJCN	0	0	451.5333	531.3333333	548.6666667	592.7333333
	# Detected by China	151.033	140.786	168.5667	163.1	179.9666667	200.4333333
	Total AJCNS	0	1	1	2	3	6
	AJCN Losses	0	0	1	1	2	4.366666667
MOE#1	Force Exchange Ratio	0.87492	0.89805	0.449475	0.636385	0.118887867	0.142010077
	US_Killed/China_Killed						
MOE#2	Fractional Exchange Ratio	0.38425	0.3897	0.197381	0.275901	0.051505792	0.06146557
	US_Kid/US/Ch_Kid/Ch						

Figure 30. POA2 Results Table (Mean Values for all Data Recorded)

The averaged raw attrition data for the US and Chinese forces is located in the upper portion of Figure 30. Each column represents a different scenario with a representative descriptive title. The column titles relate how many AJCN were in the scenario using the number of host platforms. Fratricide, acquisition and AJCN loss data are presented as the means of the 30 trials conducted for

each scenario. The numerical values for the scenario specific MOEs are also given as the mean values over all the trials.

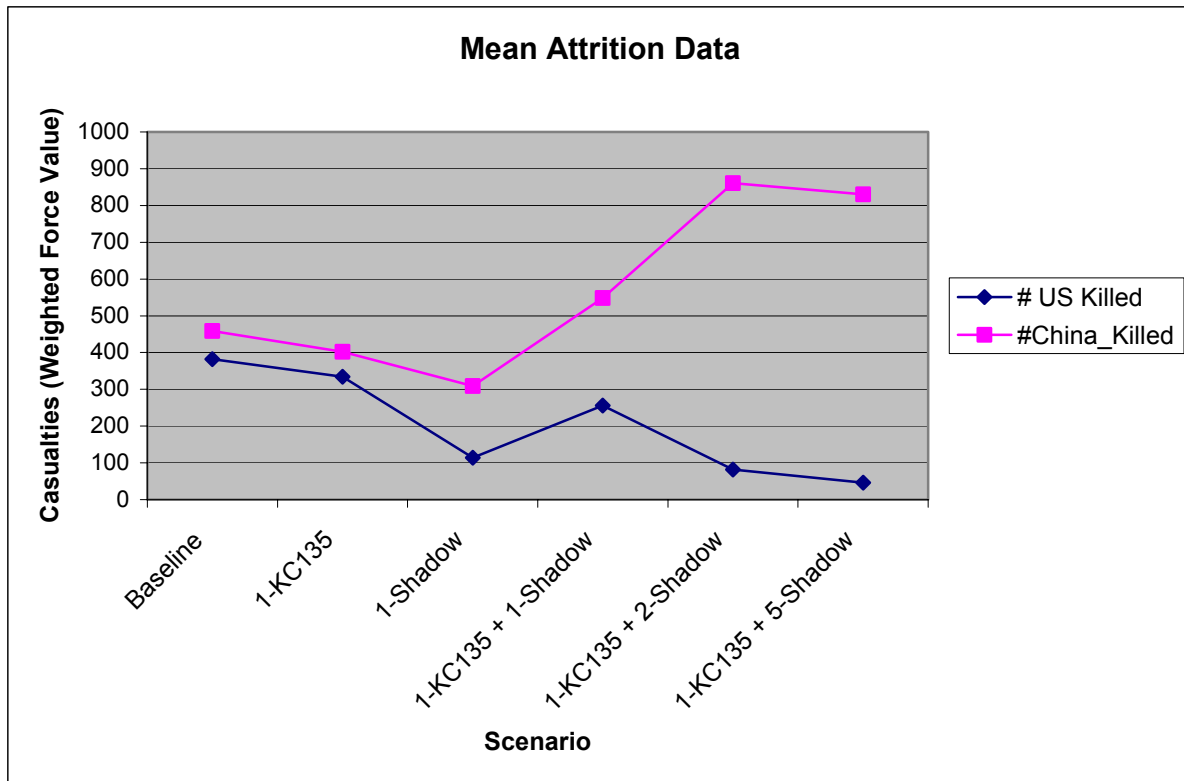


Figure 31. Mean Attrition Data for US and Chinese Forces

The Mean Attrition Data graph in Figure 31 shows a comparative view of the mean attrition data of the two forces over the six scenarios. These numbers are not relative with respect to the total quantity of forces that each side began with; this will be addressed by MOE #2. This graph does show the increase in Chinese attrition as the number of AJCNs is increased over the different scenarios. And conversely, save for the 1-Shadow and 1-KC135 scenario, how the US attrition decreases as more AJCN are incorporated into the battle.

Following the procedures outlined in Devore Chapter 10, we conducted a multiple comparisons analysis between the U.S. casualty means for each scenario. [Ref. 33] We used the Single-Factor ANOVA (Analysis of Variance) test and found that the probability of seeing such an extreme difference in the

attrition data by chance (due to Monte Carlo modeling) was 1.31×10^{-30} , far, far less than .01. In other words, the differences in attrition means are real and not due to chance. We also conducted the same test for the Chinese forces and the results were even stronger, with a probability of 2.25×10^{-32} .

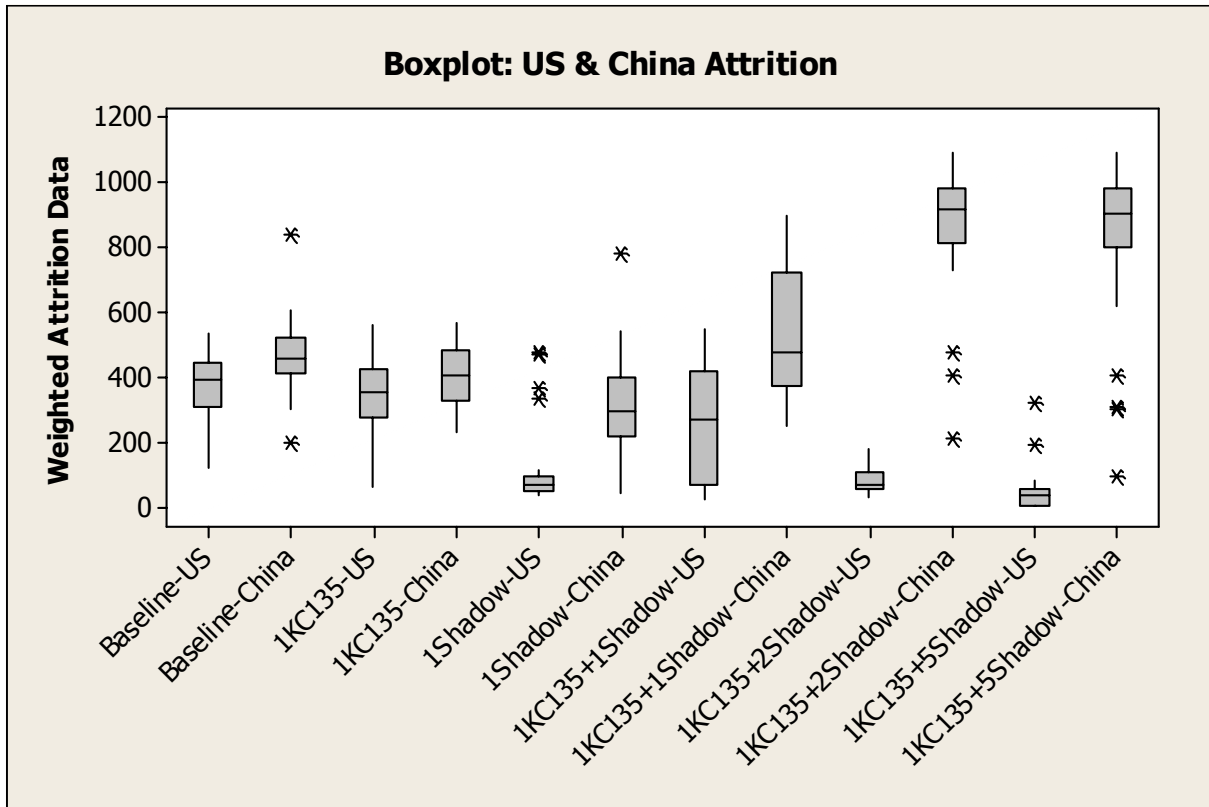


Figure 32. Mean Attrition Data for US and Chinese Forces

The boxplots of the attrition data in Figure 32 above show the paired data of US and Chinese attrition for each scenario. The mean value of Chinese forces destroyed is consistently higher than that of US forces. The first three scenarios, Baseline, 1-Shadow, and 1-KC135, produces similar results for enemy attrition, whereas the final three scenarios all produced substantial increases as the number of AJCN increased. The difference between these two groups of scenarios is the quantity of AJCN. The first three scenarios had either none or just one AJCN, while the latter scenarios had at least one AJCN operating in the low tier and one AJCN in the middle tier. This dramatic increase of 50% more

enemy attrition when more than one tier of AJCN was utilized may be traced to the increased reachback and waveform bridging capability provided through a two tier array of AJCN.

As discussed in earlier chapters, the KC-135 is the middle-tier platform for the AJCN and in these scenarios acts as the "higher echelon" link for the bottom-tier Shadow-platformed AJCN. When looking at the graph in Figure 32, we can see that when the middle or bottom-tier AJCN platform is acting alone, the enemy attrition levels remain nearly consistent with that of the baseline scenario with no AJCN systems. Once we have a bottom- and middle-tier "team" of AJCN there is the previously noted dramatic increase in enemy attrition. This "teaming" effect of using at least two tiers of AJCN coverage vice only the bottom-tier or only the middle-tier produces considerable results that can be attributed to a more stable system of coverage by enabling a self-healing network and the increased coverage provided to friendly units of both enemy and friendly situational awareness.

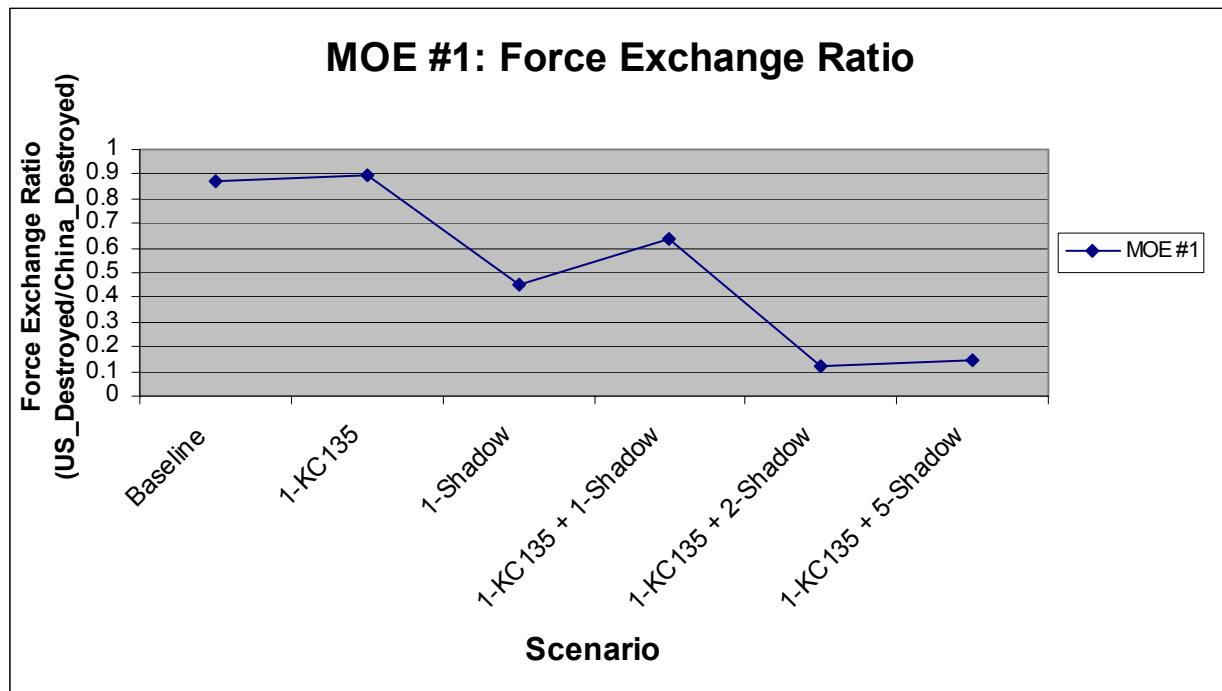


Figure 33. MOE #1 Mean Data

MOE #1, Force Exchange Ratio, gives a raw, unweighted, measure of the attrition levels of the two forces involved. The ratio is calculated by dividing the value of US forces destroyed by the value of Chinese forces destroyed. Given this formula, from the US perspective, the US wants a lower value as close to zero as possible. This conveys that the attrition levels of the enemy are greater than that of US forces.

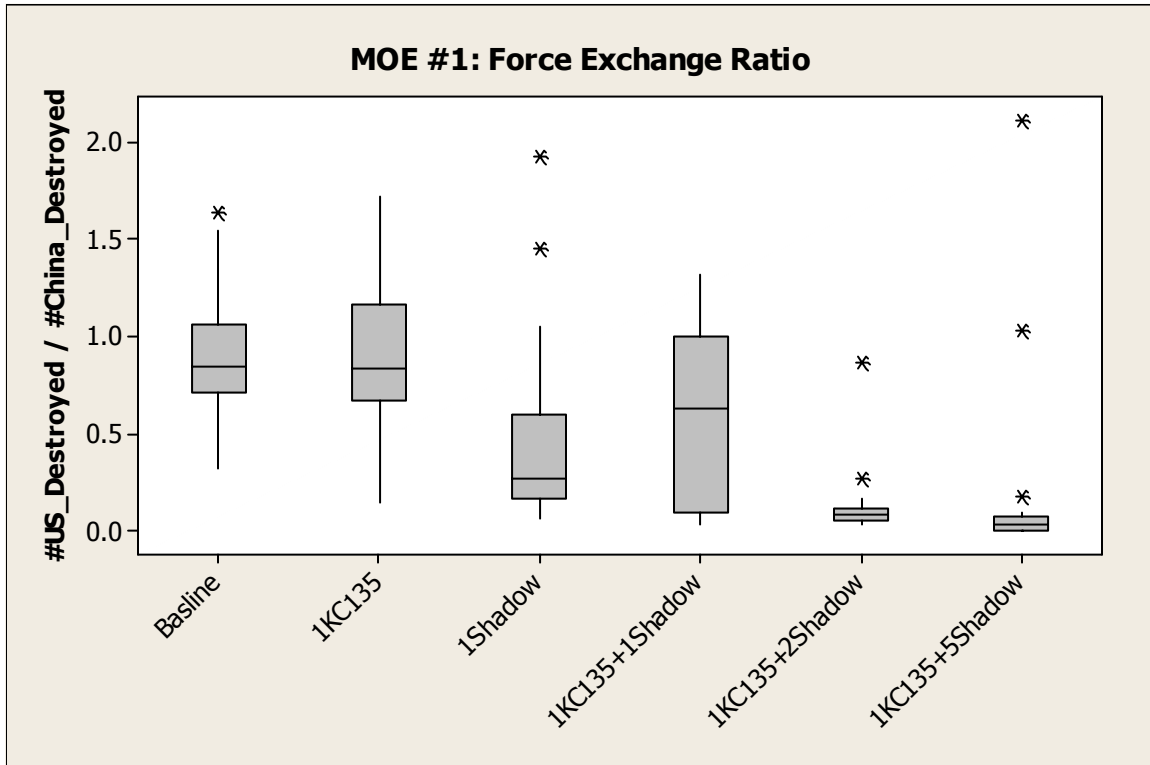


Figure 34. MOE #1 Boxplots

It can be seen in Figure 33 how the Force Exchange Ratio generally decreases over the first three scenarios, spikes during the 1-KC135 and 1-Shadow scenario, and then drops significantly for the final two scenarios. The boxplots in Figure 34 also show a greater variability in the data for the 1-KC135 and 1-Shadow scenario. Given the closed nature of the simulation, many factors may have contributed to this outcome. When looking back at the mean value chart in Figure 30, we see that at least one of the AJCN platforms is destroyed

during the course of each scenario, and except for the last scenario, 1-KC135 and 5-Shadows, we have all but one AJCN platform being destroyed. While we cannot determine when the AJCN were destroyed, when there was only one bottom-tier and one middle-tier AJCN platforms, (1-KC135 and 1-Shadow scenario) and one was shot down we have a significant increase in both friendly and enemy attrition. An increase of this level of attrition over the other scenarios relates a greater number of engagements of greater intensity. We deduce that two primary factors can explain this phenomenon: the increased situational awareness provided by the AJCN and the morale of the Chinese after shooting down a US "reconnaissance" platform. The increased situation awareness provided to the US forces may have brought them to "seek out" the Chinese positions. The increased morale of the Chinese forces may have "strengthened their resolve" when encountered by the oncoming US forces. The question then arises, why didn't this happen in the following scenarios if nearly all but one AJCN platform was shot down? An answer follows.

As noted before, the closed nature of the POA2 runs does not currently allow us to go back through and observe when the specific AJCN platform was shot down. However, given the operating range and speed of the two platforms, and the outcome of the 1-KC135 scenario we deduce that it was the Shadow UAV platforms that were shot down vice the KC-135 platform. This being assumed case, when there were more than one Shadow platform, after the first Shadow was shot down the second Shadow platform continued to provide the US forces its suite of enablers which gave the US forces a marked advantage over even a Chinese force with elevated morale.

This situation makes the case for redundancy of coverage at each of the various tiers of AJCN coverage and careful assessment of platform capabilities when deciding which platform will take the AJCN into the fight and have the greatest capability to bring it back.

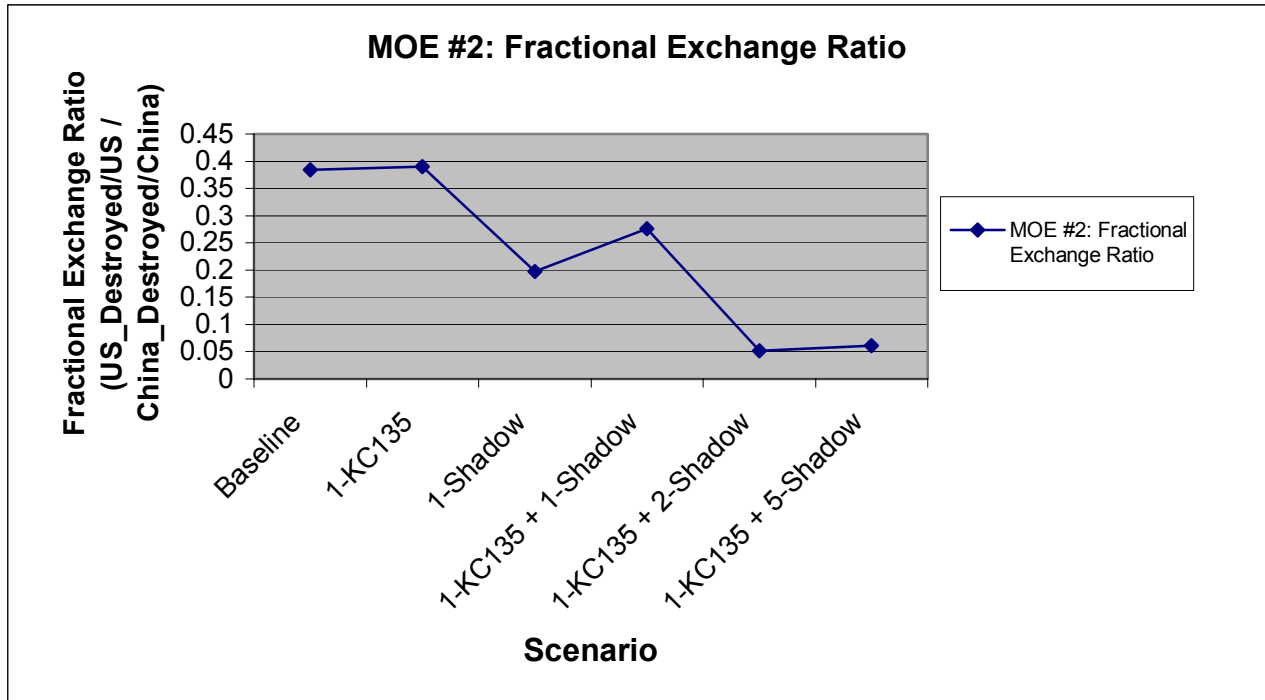


Figure 35. MOE #2: Fractional Exchange Ratio Mean Data

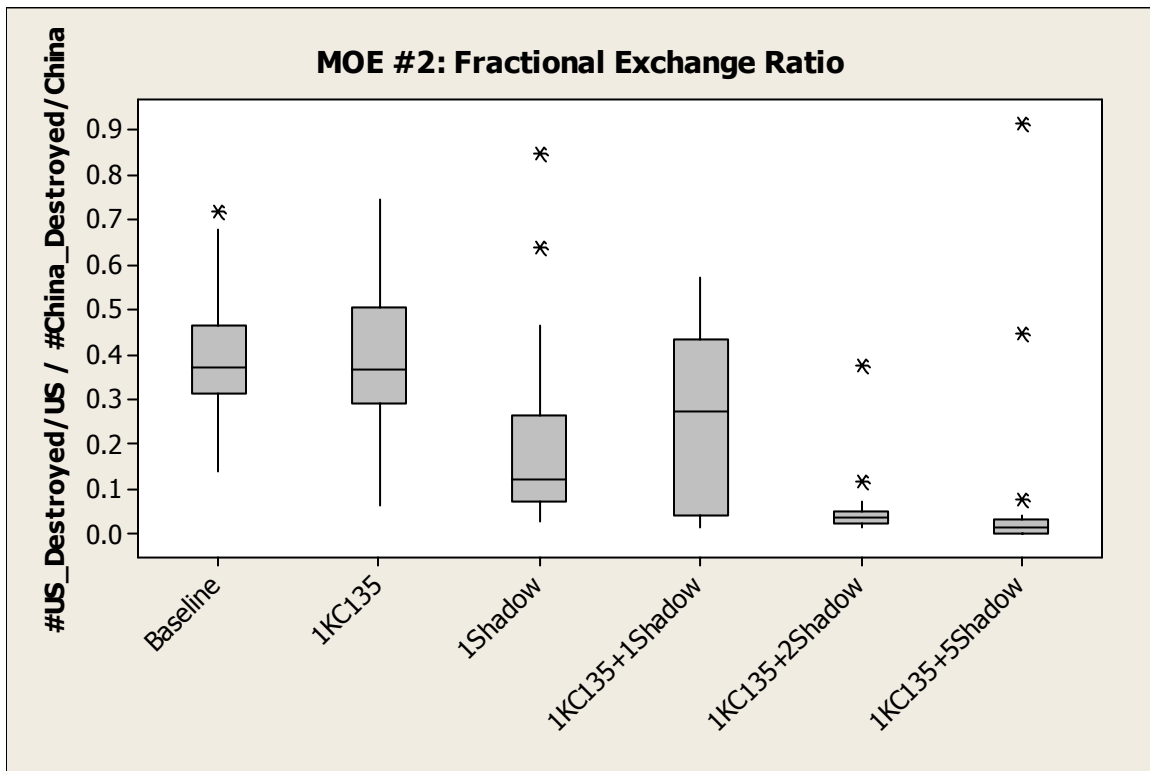


Figure 36. MOE#2: Fractional Exchange Ratio Boxplots

The Fractional Exchange Ratio, see Figures 35 and 36, provides a weighted means of evaluating the attrition of the two forces. From the US perspective, the US wants this number to be as close to zero as possible, similar to MOE #1. The data for this MOE reveals that the US lost proportionately nearly 44% fewer forces during the first four scenarios; as determined by the relative number of US forces lost during the Baseline and the 1-KC135 & 1-Shadow scenarios. However, when more than one AJCN was incorporated into one of the tiers, in this case the bottom tier, we have a distinct drop to 89% fewer forces being lost by the US; determined by the relative number of US forces lost during the Baseline and the 1-KC135 & 5-Shadow scenarios. Again, although the last two scenarios also experienced a significant amount of AJCN kills, to be discussed later in detail with MOE #5, the presence of additional AJCN platforms for even any amount of time provided the advantage to gain decisive victory to the US forces.

As previously discussed, the use of a weighted measure for the representation of the value of a system renders this MOE difficult to assess without a greater explanation of which systems are represented by the data in Figures 37 and 38. The marked increase or decrease between scenarios could be accounted for by the significant loss of individual soldiers whose weight value is one or a single tank whose weight value is 20.

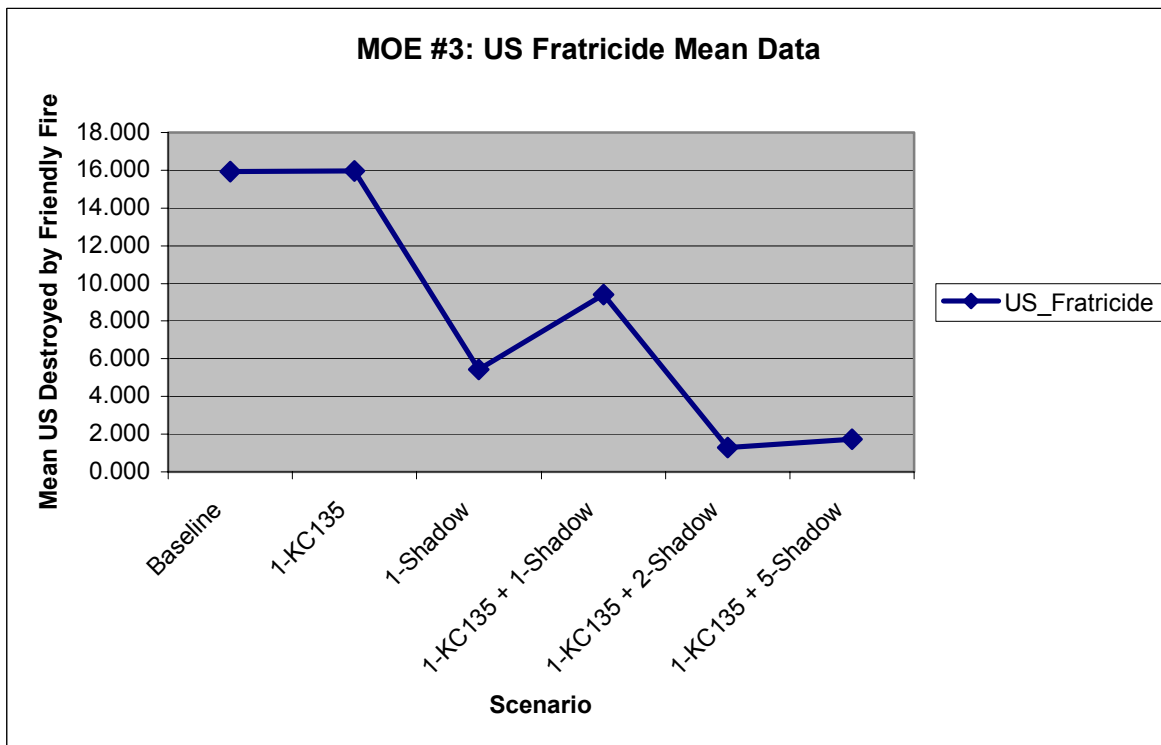


Figure 37. US Fratricide Mean Data

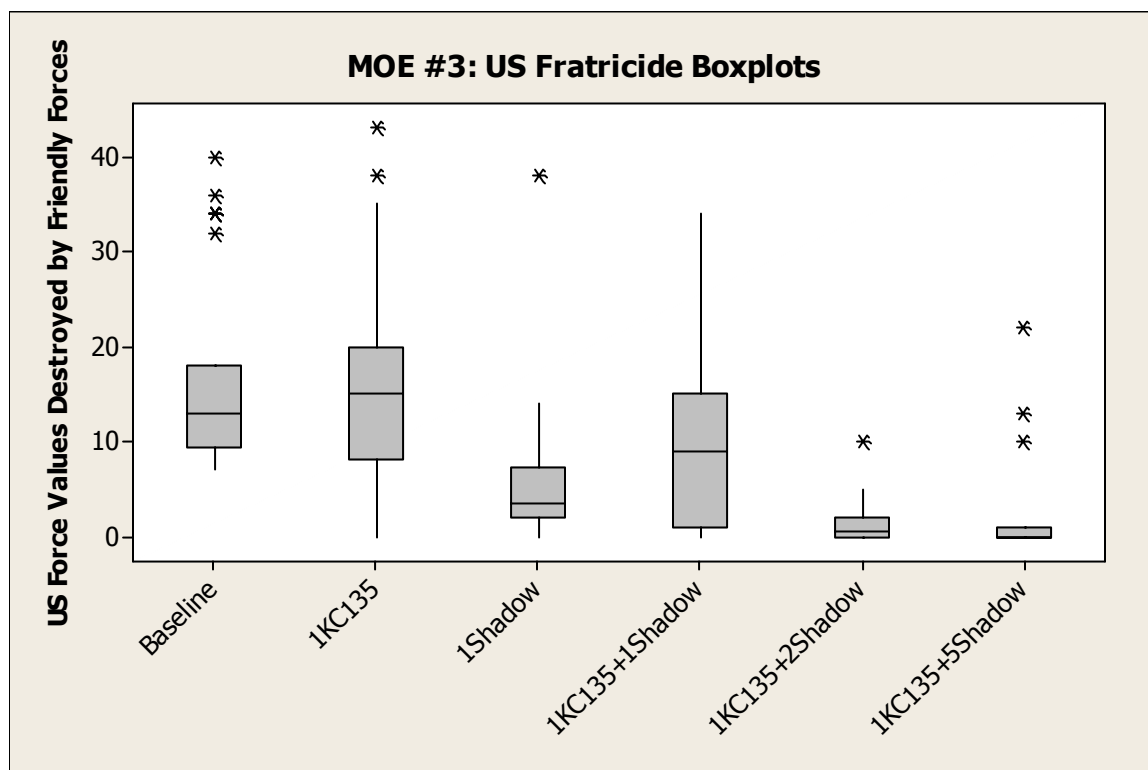


Figure 38. MOE #3: US Friendly Fire Boxplots

Figures 37 and 38 show the general negative slope of MOE #3, U.S. Fratricide. This trend confirms the concept that greater situational awareness provided to any force will decrease the number of fratricide incidents. However, there are two issues that are brought to light in the data we obtained: two tiered arrays of AJCN enable greater friendly situational awareness and situational awareness of enemy and friendly units must be comprehensively assimilated before action is taken.

The first item solidifies the two-tier concept discussed earlier in this chapter. The redundancy provided by the bottom- and middle-tier AJCN working together provides the friendly forces a marked advantage as observed through greater enemy attrition, less friendly attrition, and less friendly fratricide.

As previously noted, the 1-KC135 & 1-Shadow scenario brings a somewhat incongruous outcome: friendly and enemy attrition is higher than previous scenarios and friendly fratricide is higher. Our hypothesis for this scenario considers the benefit provided by the two-tier AJCN array combined with the early demise of the Shadow, the bottom-tier AJCN platform. We considered the following sequence of events as a possible explanation for the increased fratricide seen in the 1-KC135 & 1-Shadow scenario. The situational awareness on the enemy situation provided by the two-tier AJCN array offers the U.S. forces a quality assessment of the enemy posture. Upon the U.S. force's movement against the enemy forces the bottom-tier AJCN is shot down, degrading the updating capability for both enemy and friendly situational awareness. Based on the pre-Shadow demise, artillery missions are sequenced and fired. Fire missions incur an inordinate number of friendly casualties due to the inhibited view of the battlefield caused by the lack of redundancy in AJCN coverage.

POA 2 contains a valuable tool that does not allow for the "double" counting of acquired systems. This is key for our evaluation of the AJCN's contribution of providing a greater amount of situational awareness as measured by the acquisition of enemy units. POA 2 gives acquisition credit to the system

that gets the highest level of resolution on an enemy system. For example, a friendly aircraft observes a system on the ground but cannot determine whether it is enemy or friendly and an AJCN observes the same system and classifies it as an enemy tank. The AJCN will get the acquisition “credit” since it had the latest and highest resolution acquisition event on the enemy tank.

We see an interesting trend in the data in that the AJCN systems acquire a somewhat consistent amount of enemy systems while the acquisitions of the remainder of the US force steadily increases as the number of AJCN are increased in the scenarios, see Figures 39 and 40. This can relate the phenomena where the AJCN provides the situational awareness to the US forces that then move to engage the AJCN acquired enemy and additional supporting enemy systems and units. Thus the AJCN is not only a provider of situational awareness in itself, but it provides a mechanism for the effective positioning of friendly forces to mass their forces effectively on an enemy resulting in greater enemy attrition and lesser friendly attrition.

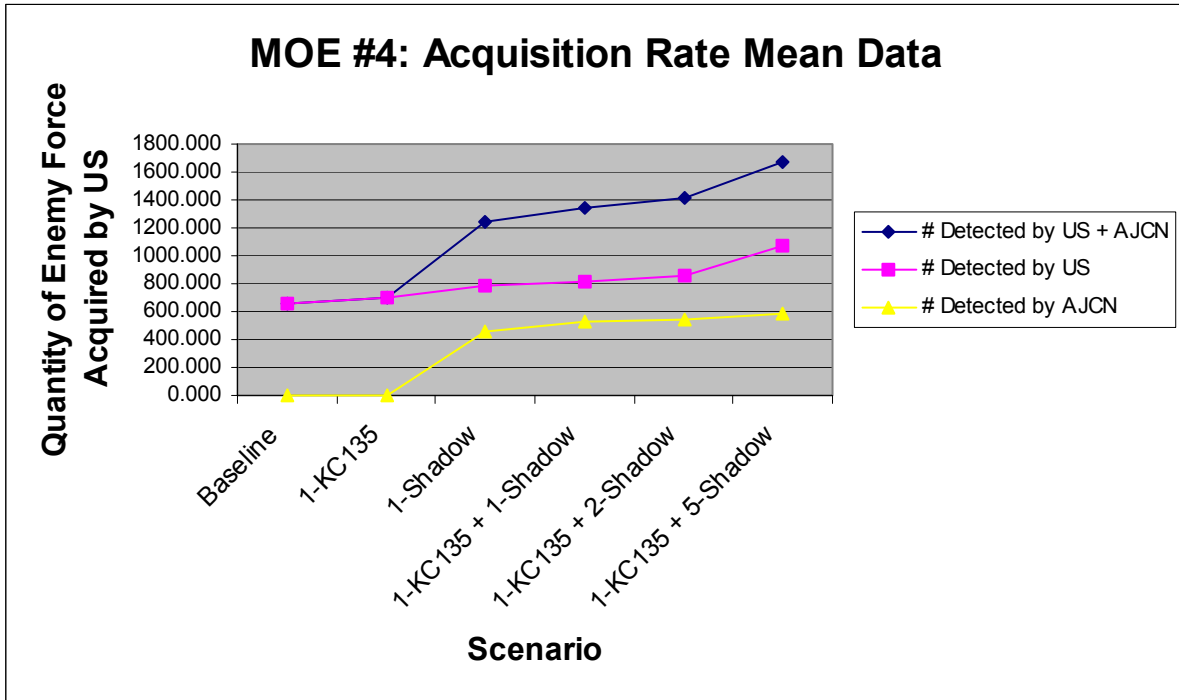


Figure 39. MOE #4: Acquisition Rate Mean Data

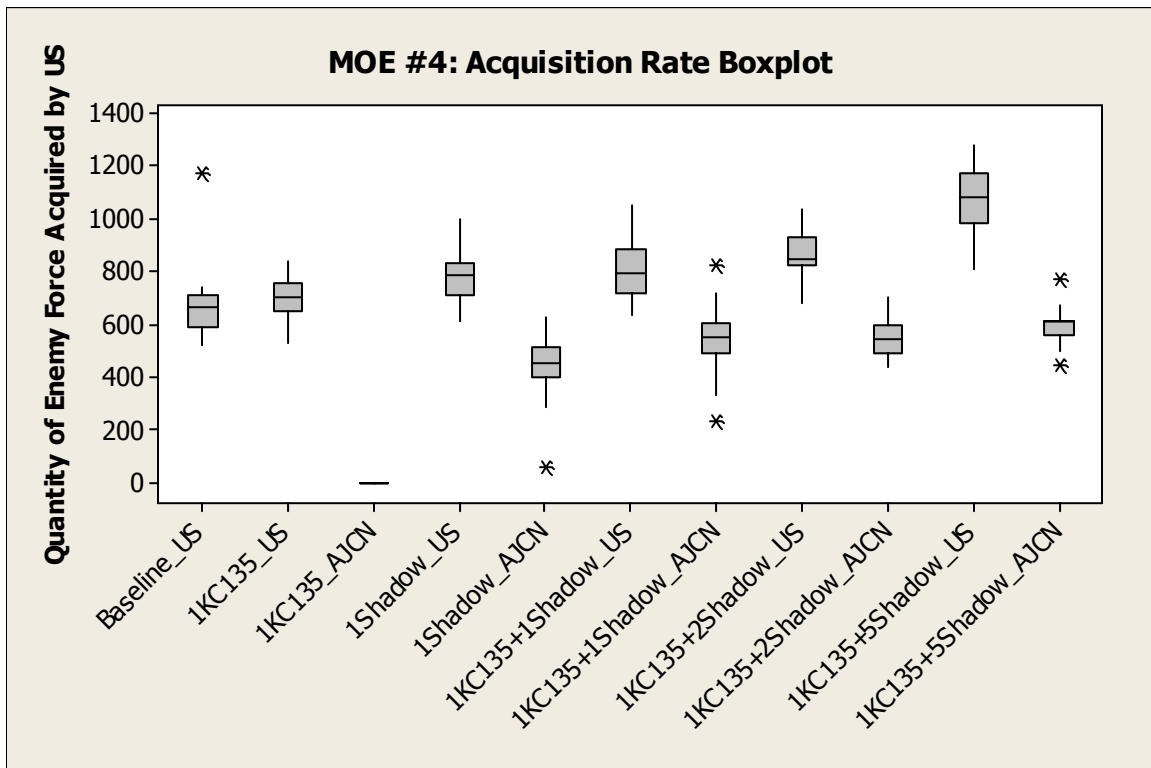


Figure 40. MOE #4: Acquisition Rate Boxplots

The POA 2 simulation does not currently let us look back through the conduct of a closed loop run to determine which AJCN platform was attritted during the respective scenarios. As stated before, given the flight profile of the bottom-tier Shadow UAV and the results from the 1-KC135 scenario, we deduce that the Shadow UAV is the AJCN platform that was destroyed during the course of the scenarios, leaving the KC135 remaining to provide overarching support to the US forces.

When looking at the difference in attrition data between the last two scenarios, we see a decrease in the number of both US and Chinese forces destroyed. There is a 44% decrease in the quantity of US forces destroyed from the 1-KC135/2-Shadow scenario to the 1KC-135/5-Shadow scenario. However, there is also a 3.5% decrease in the value of Chinese attritted. When these values are looked at in light of the number of AJCN platforms remaining in the air at the termination of the battle, we see that the final scenario of 1KC-135/5-Shadows retains an average 1.64 AJCN to the end of the scenario, see Figures 41 and 42. Again we deduce that the KC-135 remained throughout the entire scenario and that four of the five Shadows are attritted during the battle. We see that the maintenance of the two-tier AJCN array greatly impedes the Chinese ability to attrite US forces as it did in previous scenarios. This result reinforces the concept of maintaining a tiered network of AJCN to provide continuous and effective service to the forces in the air, on the sea, and on the ground.

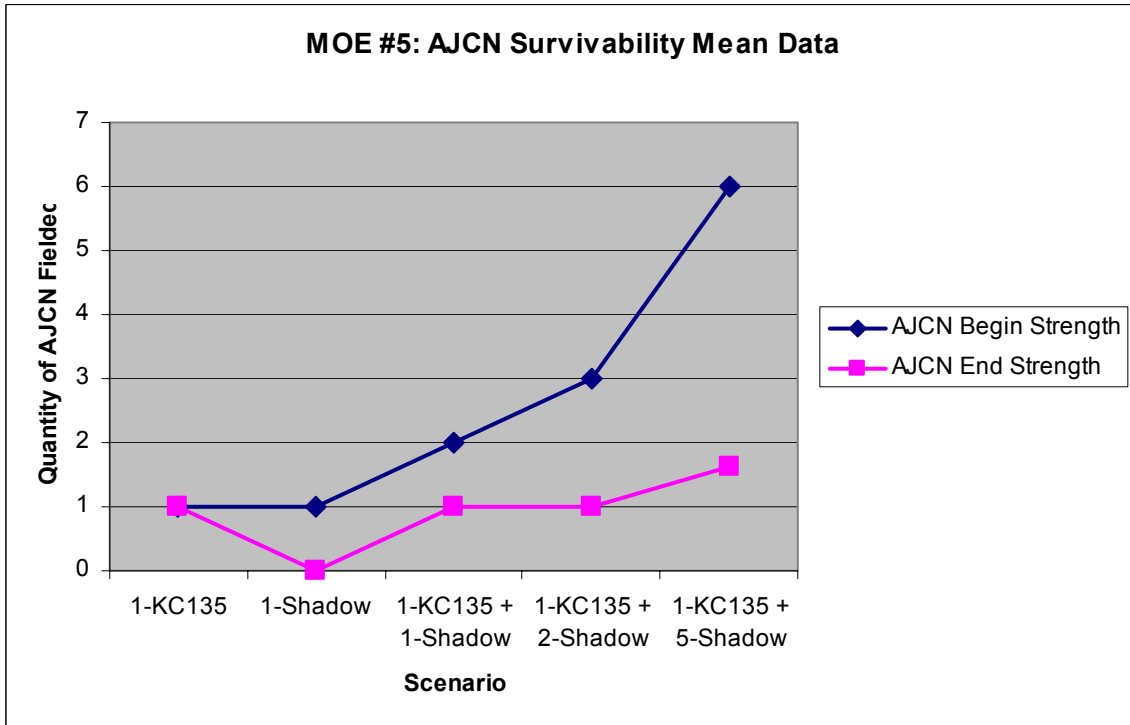


Figure 41. MOE #5: AJCN Survivability Mean Data

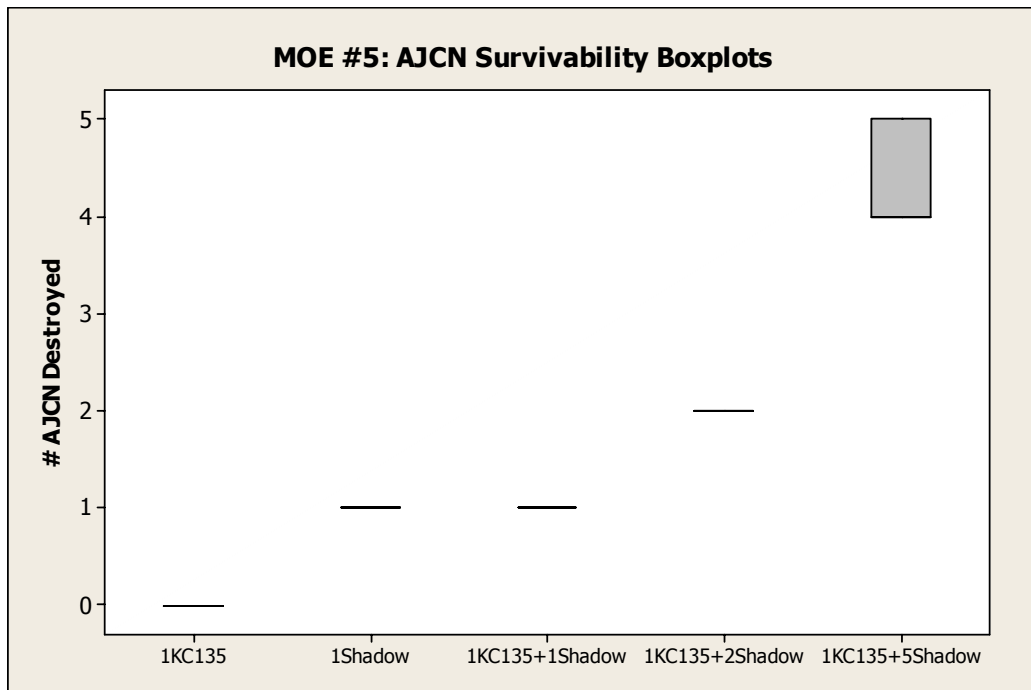


Figure 42. MOE#5: AJCN Survivability Boxplots

VII. CONCLUSION

A. PURPOSE OF THE STUDY

The purpose of this thesis was to gain insights on the employment of the AJCN as an enabler for network centric warfare. The AJCN provides interoperability between C4I systems in use throughout the DoD and the civilian sector. The wargaming and simulation of a scenario with the AJCN's capabilities modeled provide a means to glean insight into considerations that should be addressed in its development and employment.

B. WARGAME INSIGHTS

During the course of the wargame many different issues facing the employment of the AJCN surfaced. The issues addressed below are subjective in nature, based on the actions observed during the execution of the wargame. They should be considered within the context of the wargame's characteristics that affect its outcome. These two main characteristics are the scenario and the staff's level of experience. The scenario's littoral setting and the adhoc nature of the two staffs may have impacted the observations taken from this wargame. However, these issues are offset by the collaborative experience represented by the students populating the two staffs. We feel that the wargame presented a good testbed to gain the generalizeable insights we needed. The insights are formatted with respect to the behavior or response observed (Observation) followed by a means to address the issue(s) raised in the Observation (Recommendation).

1. High Priority Target

Observation: AJCN is a High Priority Target (HPT). Given a technically advanced enemy, the activities and capabilities of the AJCN will be identified and targeted by the enemy. The enemy's capability to target and destroy the AJCN is directly related to the platform being used to transport the AJCN. Consideration must be given to the survivability of the supporting platform given the mission and terrain over which it will operate. The use of "slower" and lower altitude platforms should be carefully monitored and adjusted to the capabilities of enemy

air defense and aviation capabilities. This issue was addressed in detail in a thesis drafted by Craig J. Werenskold where he referenced the vulnerability of Hunter UAVs to both surface to air missiles and unconventional enemy tactics during the Kosovo conflict. Serbian forces would fly a Mi-8 HIP helicopter alongside the UAV and destroy it using machine gun fire. The effective enemy tactic was countered by a concerted Allied air campaign against Serbian helicopter operations with NATO strike fighters. [Ref. 24] This example reinforces the key role that in depth Intelligence Preparation of the Battlefield (IPB) and the planning of any Air Tasking Order (ATO) play in the effective employment of the AJCN's capabilities.

Recommendation: The selection of the AJCN's supporting platform must consider the platform's survivability characteristics paired against the enemy's capabilities of engaging that platform.

The AJCN's electronic jamming capabilities may be required to act as a means of self-preservation against enemy air defense units. This use of channels for "self-defense" needs to be considered during the AJCN Tasking process to alleviate the possible in-course reallocation of channel resources to accommodate self-defense and the consequent dismissal of another previously planned mission.

The AJCN Planning SOP should include a recommended number or percentage of channels that can be reserved for self-defense and during mission allocation.

2. Vulnerable During Early Entry Operations

Observation: AJCN is vulnerable during early entry with no air supremacy. The use of UAVs in recent campaigns consistently sees them being used autonomously as gatherers of intelligence or providers of targeting information to assets that are not local to the UAV and are definitely not providing any protective coverage for the UAV. Given the AJCN's SIGINT and Information Warfare (IW) capabilities, it is implied that the AJCN's supporting air platform be in a position of possible vulnerability to enemy air forces and air defense assets

and the time requirement of the intelligence provided by the AJCN may not allow the achievement of air superiority prior to their employment. Without an active self defense mechanism inherent to the supporting air platform, the primary method of defense is altitude. If the supporting platform operates above the range capabilities of the enemy air defense and above the "normal" operating altitude of enemy air forces, then it inherits a different level of security than if operating at lower altitudes.

Recommendation: During initial phases of operation, use only AJCN supporting platforms that can operate at altitudes above expected enemy air defense ranges and enemy air force operating altitudes. Also, consider ground-based platforms for AJCN.

Ground-based platforms could be integrated into early entry and conventional forces deployment to provide the AJCN's capabilities to the force without unnecessarily endangering an aerial platform. The AJCN should be emplaced on terrain features that maximize its effectiveness (i.e. a terrain feature that gives it an unobstructed "view" of the battlefield).

3. AJCN Seen as Its Platform

Observation: Commanders did not devote enough attention to planning and using the resources provided by the AJCN. This observation may have its roots within the context of the wargame itself; however, the actions of the commanders and their staff should be addressed considering the participants are those that will fill actual staff roles in the future.

The AJCN was seen as its platform. Namely, the UAV the AJCN's capabilities are mounted on. The lesson here is that a UAV by any other name is NOT just another UAV. Although additional capabilities were inherent with the AJCN-UAV, the capabilities and employment considerations were not exploited to maximize the AJCN's effects on the battlefield. The AJCN-UAV was used in a manner "normally" associated with UAVs with respect to an intelligence-gathering mode of employment.

Recommendation: The employment of a new system requires the education of those who will employ it. This process should not only educate the operators who will physically operate the system, but the commanders, and their staffs, who will decide the best manner to deploy the system.

Great caution should be taken when considering the air platform upon which the AJCN will be mounted with respect to any other capabilities that are "mounted" or inherent to the air platform. If the air platform has varying and competing capabilities mounted upon it, then decisions will be made based on which mission capability has "priority" for a certain period of time. This conflict greatly diminishes the combat effectiveness of the AJCN and any other system co-mounted on the air platform.

Significant effort should be made to configure air platforms with systems that complement not only each others capabilities but allow for a synergistic multiplication of effects on the battlefield. An example would be the AJCN mounted on an Unmanned Combat Air Vehicle (UCAV) with laser designator capabilities. Using the SIGINT capabilities, the AJCN can identify a large source of electromagnetic energy related to a large enemy command center; translate this information into targeting data that the laser designator can lock in on which will guide the Hellfire missile mounted on the UCAV to its target.

4. Need for Effective Information Processing

Observation: Unless resources are dedicated to assimilate information in a meaningful manner, the benefits provided by the AJCN will be limited. During the course of the wargame, information provided by the AJCN was disseminated to the other units in the effected areas but there was no collective assimilation of the information at a higher level to allow for evaluation and analysis. This occurred due to the primary reason of personnel availability, but brings forth the issue of data presentation and manipulation through the CRS.

Recommendation: Ensure that the CRS provides the ability for operators/analysts to quickly obtain and manipulate data in a manner that it can

be presented to the commander and his staff so that allows for quick assimilation of and action upon the information may be taken.

5. C2 of AJCN

Observation: Command and control of AJCN assets must be clearly delineated in advance with a continuing mechanism to smoothly shift priorities/ownership to the needs of the commander. The capabilities provided by the AJCN incur a great deal of requests for use by separate commanders who deem their portion of the mission the most crucial. UCAV use in Afghanistan provides a clear example of the requirement for a solid chain of command to oversee their use. During the course of operations, UCAV control stations would receive calls from high-ranking commanders in the area requesting the use of one or more UCAVs. The UCAV control stations referred them to their superiors at higher headquarters.

Recommendation: The AJCN's capabilities mandate that the highest levels of the CoCom's staff be involved in the allocation of its resources. Also, a certain amount of rank should be inherent to the AJCN's control section to prevent any misuse or abuse of the AJCN for missions not properly channeled through the CoCom's staff.

6. Adjustable "Radius of Coverage" for AJCN Waveform Bridging

Observation: In order to deconflict communications between ground units, the radius of the AJCNs waveform bridging capabilities must be constrained. This implies that the AJCN platform may have to fly at a lower altitude to constrain the radius of coverage to only those ground combatants requiring the capability. An example of how the AJCN's radius of capabilities would be detrimental is when it operates above a Unit of Action (UA). The Unit of Employments (UE) comprising the UA may use some of the same frequencies for communications in their subordinate units. Only due to the range between the UE's do these separate units not "step" on one another during the course of operations. If the AJCN were scheduled to "bridge" a UE frequency to a Marine unit operating on its right flank and the UE to its left flank shared that same frequency; then both units within both UE's operating on that frequency would be

talking to the Marine unit. This "over-bridging" by the AJCN could incur a great deal of miscommunication between the units and possibly result in dangerous conditions for them.

Recommendation: Develop the capability to adjust the radius, or cone, of coverage of the AJCN's waveform bridging capability to negate the possibility of causing an unnecessary and possibly dangerous overlap of communication networks.

C. SIMULATION INSIGHTS

Insights gleaned from the POA 2 simulation runs reinforce issues seen during the execution of the wargame and reveal some additional items not previously addressed. The simulation's small scale scenario lends itself to provide foundational insight which can be extrapolated to relate to larger scenarios. Issues that correspond with a wargame insight will reference the paragraph number from the Wargame Insights Section to address the similarity of findings.

1. Careful Assessment of Supporting Platform Performance Parameters

Observation: Bottom-tier AJCN platforms were consistently engaged and destroyed. This insight corresponds well with insight numbers 1 and 2 from the previous section, Wargame Insights. These addressed the designation of an AJCN carrier platform as a high priority target and the vulnerability of UAV systems that operate in at altitudes below 25,000 feet. In the POA 2 runs the Shadow-mounted AJCN were consistently engaged and destroyed, whereas the KC-135-mounted AJCN were not destroyed during the runs.

Recommendation: The consistent engagement of the low altitude and relatively slow-flying Shadow UAV platform reinforces the need for a detailed assessment of enemy air defense capabilities when planning AJCN operations. Both vehicle-mounted and shoulder-fired weapon systems must be considered for a proper threat assessment.

2. Use of "Decoy" Systems During Initial Phase of Battle

Observation: The final scenario, 1-KC135 and 5-Shadows, ended with at least one bottom-tier AJCN platform still operating. The three to four other bottom-tier platforms essentially served as "decoys" to "gainfully employ" the enemy air defense systems.

Recommendation: Use decoy aerial platforms to "gainfully employ" enemy air defense systems during the early stages of the battle to increase the AJCN platform's survivability. Decoys may come in the guise of less expensive UAVs or in a chaff system that is deployed from the AJCN platform when engaged by enemy air defense systems.

3. Maintain 2-Tier Coverage

Observation: The POA 2 data consistently revealed an advantage to US forces when two tiers of AJCN coverage were maintained for a greater portion of the battle. The two-tier coverage serves to increase the area of AJCN coverage and to ensure consistency of coverage provided by a self-healing network of redundant AJCN capability.

Recommendation: The AJCN should be employed in a tiered array to maximize its contribution to the supported forces. A minimum of two tiers should be employed to increase the quantity and quality of services provided to the supported force.

D. FUTURE WORK

This thesis has great opportunities for future work with respect to more detailed analysis of the AJCN system and in the evaluation of constructive simulation database generation and maintenance. The AJCN is still within the Advanced Concept Technology Development (ACTD) process, and thus the final design and employment can be greatly influenced by future analysis of the system through the use of wargaming and simulation. The lessons learned during the course of this thesis concerning the vital importance of a solid database foundation upon which to build a simulation experiment can also be a venue for further study.

1. Continued AJCN Analysis

The use of a live wargaming event to gain insight into the employment of the AJCN was invaluable. However, further analysis could be done using a constructive simulation model to facilitate the generation of analytical results. Using a constructive simulation would afford the ability to conduct multiple runs in multiple scenarios to achieve an even greater breadth of insight than that accomplished in this thesis.

The choice of constructive simulation should be based on the research questions that are seeking to be answered and the simulation's ability to accommodate the gathering of data to fulfill the Measures of Effectiveness' data requirements.

2. Database Analysis of DoD Constructive Simulations

A great learning point generated through this thesis was the vital importance of an accurate database. The database is foundational to the successful execution of any type of simulation for both analytical and training purposes. A possible topic of research is to investigate the database content and management of a subset of the constructive simulations used within the Department of Defense or one of the services within DoD.

LIST OF REFERENCES

1. Garstka, John J., "Network Centric Warfare: An Overview of Emerging Theory." [Joint Staff Directorate for C4 Systems] (Dec 2000 [cited 6 August 2004]); available from the World Wide Web @ <http://www.more.org/publications/phalanx/dec00/feature.htm>
2. Adaptive Joint C4ISR Node (AJCN) Advanced Concept Technology Demonstration (ACTD) Interim-Joint Military Utility Assessment (I-JMUA) Concept of Operations (CONOPS) Version 1.0. (31 March 2004).
3. Department of Defense Financial Management Regulation, Volume 1, Chapter 2, page 5. [(cited 12 June 2004)] Available from the World Wide Web @ http://www.dod.mil/comptroller/fmr/01/01_02.pdf
4. U.S. Code, Title 10, Subtitle A, Part 1, Goldwater-Nichols Act of 1986 [(cited 1 June 2004)] Available from the World Wide Web @ http://www.dtic.mil/jcs/core/title_10.html
5. Briefing given by CAPT Hansen on 3/29/04 and 3/30/04. Available on the World Wide Web @ http://nps.blackboard.com/webapps/portal/frameset.jsp?tab=courses&url=/bin/common/course.pl?course_id=_4051_1
6. Haag, Jason L. "OIF veterans discuss lessons." [(cited 15 August 2004)] Available from the World Wide Web @ <http://www.af.mil/news/story.asp?storyID=123005347>
7. Perla, Peter P. *The Art of Wargaming: A Guide for Professionals and Hobbyists*. Annapolis: United States Naval Institute, 1990.
8. Adaptive Joint C4ISR Node System Operational Concept (ACTD Version 1.2), 8 April 2003.
9. Tzu, Sun. *The Art of War*. Trans. Samuel B. Griffith. Oxford: Oxford University Press, 1963.
10. Field Manual 101-5, Staff Organization and Operations, Final Draft. Washington, D. C.: Department of the Army, 1996.
11. Companion, Michael, & Mortimer, Charles. *Designing for Change: A modeling and Simulation System Approach*. ([15 February 2004]) Available on the World Wide Web @ <http://www.link.com/pdfs/itsec2.pdf>
12. Department of Defense 5000.59-P, "Modeling and Simulation Master Plan", October 1995.

13. Joint Publication (1-02).
14. Simulation Officer's Handbook, Version 1.0, October 30, 2003.
15. United States Army Redstone Technical Test Center (RTTC). "What We Do; Modeling, Simulation, and Hardware/Human-in-the-Loop Technology Integrated into Testing." ([cited 15 August 2004]) Available on the World Wide Web @ http://www.rttc.army.mil/whatwedo/primary_ser/modeling.htm
16. Chairman of the Joint Chiefs of Staff Instruction (CJCSI 3170.01C) "Joint Capabilities Integration and Development System."
17. JRTS Overview. ([cited 16 August 2004]) Available on the World Wide Web @ http://jtrs.army.mil/sections/overview/fset_overview.html
18. Hunter UAV Forum. ([cited 17 August 2004]) Available on the World Wide Web @ <http://www.uavforum.com/vehicles/production/hunter.htm>
19. Office of the Secretary of Defense Unmanned Aerial Vehicle Reliability Study. Design, Performance and Analysis of Unmanned Aerial Vehicle Systems, Short Course 7-11 April 2003. Monterey, CA.
20. Shimamoto, Faith. *Simulating Warfare Is No Video Game*. ([cited 19 August, 2004]) Available on the World Wide Web @ <http://www.llnl.gov/str/Shimamoto.html>
21. JCATS Standard DB Initiative.ppt (on H: drive)
22. Peck, Michael. *National Defense Magazine*, May 2003, Feature Article, "Pentagon Unhappy About Drone Aircraft Reliability, Rising Mishap Rates of Unmanned Vehicles Attributed to Rushed Deployments," ([cited 19 August, 2004]) Available on the World Wide Web @ <http://www.nationaldefensemagazine.org/article.cfm?id=1105>
23. "PRC Begins Week-Long War Games." Reuters, 17 July, 2004. ([cited 19 August 2004]). Available on the World Wide Web @ <http://taiwansecurity.org/Reu/2004/Reuters-170704.htm>
24. Werenskjold, Craig J. "The Effect of Unmanned Aerial Vehicle Systems on Precision Engagement." Thesis, June 2002. Naval Postgraduate School, Monterey, CA.
25. HPS Simulations, P.O. Box 3245 Santa Clara, CA 95055-3245.

26. Kaplan, Ian, and Kaplan, Linda. Pseudo-random Numbers. ([cited 1 September 2004]). Available on the World Wide Web @ http://www.bearcave.com/misl/misl_tech/wavelets/hurst/random.html
27. Hamilton, Scott S. (1997). *Aide De Camp -2 User Manual* [Software]. HPS Simulations, Santa Clara CA.
28. Hamilton, Scott S. (2003). *Point of Attack -2 User Manual* [Software]. HPS Simulations, Santa Clara CA.
29. Glossary Terms. ([cited 15 December, 2003]) Available on the World Wide Web @ http://cia.gov/ciao_document_library/glossary/C.htm
30. U.S. Army Field Manual 8-10-3 Division Medical Operations Center Tactics, Techniques, and Procedures-Glossary. Washington, D.C., Headquarters Department of the Army.
31. McCarthy, Michael. Informal discussion in June 2004. Monterey, CA.
32. MK19 40mm Machine Gun, MOD 3 (Weapon Characteristic Summary). ([cited 9 September 2004]) Available on the World Wide Web @ <http://www.fas.org/man/dod-101/sys/land/mk19.htm>
33. Devore, Jay L. *Probability and Statistics for Engineering and the Sciences, Fifth Edition*. Pacific Grove: Brooks/Cole 2000.

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